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RAFFERTY-ALAMEDA PROJECT

ENVIRONMENTAL IMPACT STATEMENT

Souris Basin
Development
Authority

CHAPTER 7

HYDROLOGY

RAFFERTY/ALAMEDA ENVIRONMENTAL IMPACT STATEMENT

CONTENTS

Executive Summary Report

Chapter 1 Project Description

Chapter 2 Social & Economic Circumstances

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Chapter 4 Public Involvement

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Chapter 9 Soils

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Chapter 16 Heritage Resources

Chapter 17 Recreation
  (a) - Recreation General
  (b) - Lutheran Bible Camp
  (c) - Dr. Mainprize Regional Park

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FORWARD

At the request of the Souris River Development Authority, Saskatchewan Water Corporation undertook a study of the hydrologic impact of the proposed Rafferty and Alameda Reservoirs and the Boundary to Rafferty diversion channel.

This report, which documents the results of the study, is to become a reference document for the Project's Environmental Impact Statement and was developed primarily for that purpose.

SYNOPSIS

The report presents a description of the hydrologic regime affected by the proposed Rafferty and Alameda Reservoirs and a Boundary to Rafferty diversion channel (Project) under pre and post-project conditions. To demonstrate the potential hydrologic impact, computer models were used to simulate the hydrologic regime of the river with and without the Project, using reconstructed monthly mean natural flows for the period 1912 to 1981. The study also included an assessment of the flood control capability of the Project.

The study results show that the Project will increase water management flexibility by allowing Saskatchewan to better control its entitlement to the annual natural flow of the Souris River basin. The reservoir storage will allow localized development of new municipal, industrial, agricultural and instream uses and provide capability for water-based recreation. The Project will also provide the capability to significantly reduce the flooding potential downstream of the reservoirs.

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CHAPTER 1

OVERALL APPROACH

1.1 INTRODUCTION

This report describes the potential hydrologic impacts from the proposed Rafferty and Alameda dams and reservoirs and the Boundary to Rafferty diversion channel. These hydrologic impacts are defined in terms of changes in reservoir elevations and flow conditions that are expected to occur from month to month and year to year. They have been determined with the aid of specialized computer simulation models. The report sets out the methodology, describes the data, models and assumptions used in the analyses and provides a set of results that represent the potential characteristics of the future hydrologic regime.

Chapter 1 provides an overview of the project and the approach used to evaluate the hydrology. Chapter 2 describes the hydrology before the projects which reflects the current situation respecting water use, supply and flooding. Chapter 3 describes the hydrology after the projects, with a detailed description of the models, data and assumptions that were used for the analysis. Chapter 4 brings the results from Chapters 2 and 3 together to enable a comparison of the pre and post-project hydrologic conditions.

Chapter 3 includes a discussion of the guidelines that have been developed for operating the reservoirs. The operating guidelines specify how the reservoirs will be operated to reduce flooding downstream of the reservoirs and how the total water supply will be shared between Saskatchewan and the United States. These guidelines had to be negotiated with the United States since they will be contributing financially. A tentative agreement has been reached on guidelines for sharing the water and agreement in principle has been reached for operating the reservoirs during floods.

Although there exists Interim Measures from the International Joint Commission (IJC) on how the water of the Souris River basin should be shared, some potential changes to the existing arrangement were negotiated between Saskatchewan and the United States. These potential changes are considered to conform to the Boundary Waters Treaty of 1909 and to maintain the spirit and intent of the IJC Interim Measures, but must be examined in detail by both federal governments and agreed to by provincial and state governments.

The tentative agreement reached on this sharing arrangement recognizes that because this is a multi-purpose project and there will be relatively large evaporation losses that experienced on Rafferty and Alameda Reservoirs, Saskatchewan should be entitled to a share of water that is larger than that specified in the Interim Measures. Although each jurisdiction will be entitled to equal shares of the annual natural flow, North Dakota has agreed to take some of its share in certain years as a portion of the evaporation losses from Rafferty and Alameda Reservoirs.

The concept of such an arrangement was identified by the IJC in its 1978 report, "Water Apportionment in the Poplar River Basin." In commenting on the operation of future reservoirs they said:

> "If either country requests the other to store temporarily a portion of its share of the water yield, the country providing such a service should be compensated. Such a compensation could be in the form of a higher credit for water delivered . . . . "
> ". . . . water lost through evaporation while held in storage should be taken into account when determining compensation."

1.2 PROJECT DESCRIPTION

A detailed description of the overall project can be found elsewhere in the Environmental Impact Statement (EIS). For purposes of the hydrologic studies, the project was assumed to have the Rafferty and Alameda Dams and the Boundary to Rafferty diversion channel situated in the basin as shown on Figure 1.1. The general physical characteristics of the reservoirs are shown in Table 1.1. The maximum capacity of the diversion channel was assumed to be 60 m^3/s.

TABLE 1.1

RESERVOIR CHARACTERISTICS

Condition	Rafferty Reservoir Site C Elevation (m)	Storage (dam^3)	Area (ha)	Alameda Reservoir Elevation (m)	Storage (dam^3)	Area (ha)
Maximum Flood Control Storage 1)	554.0	632,400	6,217	579.0	183,000	2,210
Maximum Water Supply Storage 2)	550.5	439,500	4,877	574.0	96,600	1,340
Minimum Operating Storage 3)	537.5	9,660	1,176	564.0	18,900	380

1) This criterion represents the maximum quantity of water that can be safely stored during flood conditions and generates the highest elevation to which water will be stored in the reservoir.

2) This condition is targeted for as soon as possible after a flood.

Water will only be stored above this elevation to reduce the potential for flood damage downstream and will be released as soon as possible in a controlled manner that does not contribute to flood damage downstream.

3) This condition is represented by the minimum elevation at which releases can be made from the reservoir.

Detailed area-capacity elevation curves can be found with the discussion of the water supply modelling in Chapter 3.

In conjunction with other water developments in the basin, i.e. dams and reservoirs, this project will provide water to meet the cooling requirements of the Shand generating station downstream of Estevan; develop new irrigation; meet Saskatchewan's obligations for international apportionment of the Souris River; and, meet foreseeable future demands for domestic, municipal, industrial, recreation, wildlife and livestock needs.

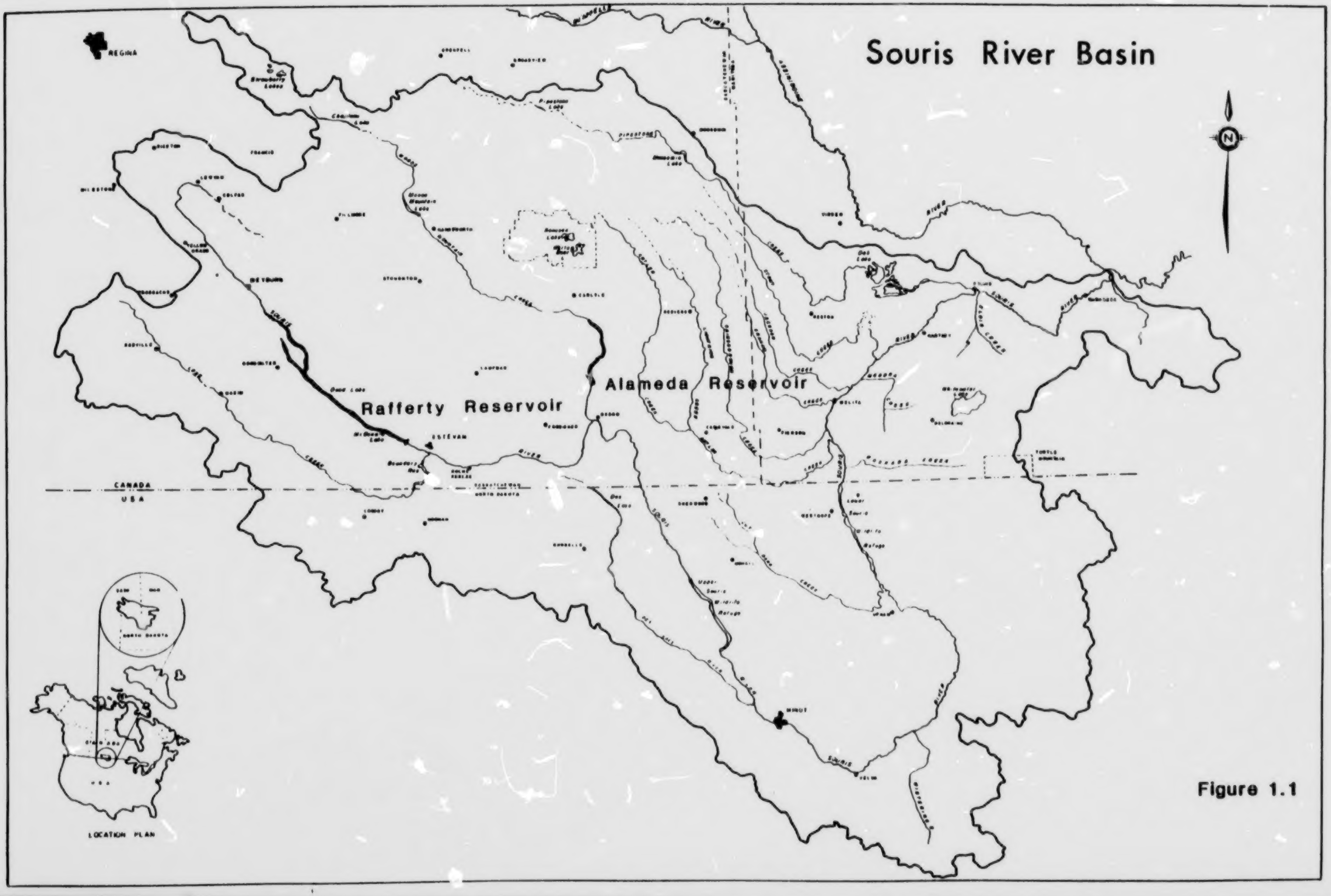

Souris River Basin
N
REGINA
Rafferty Reservoir
Alameda Reservoir
ESTEVAN
CANADA
USA
MINOT
LOCATION PLAN

Figure 1.1

1.3 PREVIOUS STUDIES

In the hydrologic evaluation of this project, information from a number of previous studies was used to develop data and assumptions. These studies are briefly described subsequently to provide the reader with an understanding of the history of investigations related to this project.

1.3.1 Saskatchewan-Nelson Basin Board (SNBB) Studies

The SNBB was a joint federal-provincial group organized in 1968 to provide a detailed assessment of water supply, use and management in the Saskatchewan-Nelson River system. Natural streamflows for the period of record from 1912 to 1967 were developed for numerous river basins across the prairies including several stations in the Souris River basin. A computerized mathematical model was also developed to estimate water supply for several water storage projects within the Saskatchewan-Nelson River basin.

One of the many storage proposals examined in the SNBB study was the Rafferty Dam on the Souris River. The assignment was undertaken by Prairie Farm Rehabilitation Administration (PFRA) and it included field and office investigations plus design and cost estimates for the SNBB (Ref. 1).

1.3.2 Souris River Basin Study

In 1974 the Souris River Basin Board, comprised of representatives of the governments of Canada, Saskatchewan and Manitoba, undertook a study of the management of water and related resources in the Canadian portion of the Souris River basin.

The report, published in 1978 (Ref. 2) examines flood damage reduction, water supply, water quality, water-related resources, agriculture, economics, an evaluation framework and legal, administrative and institutional aspects. During this study PFRA was engaged to carry out hydrology studies, develop natural flows at key points in the basin and carry out computerized water simulation studies for water supply storage projects in the basin. A total of 55 hydrometric stations in Canada and the United States were utilized in the hydrologic study of the entire Souris River basin. Using this base hydrologic data and applying the historical water uses, mean monthly natural flow estimates were derived at 20 key points in the basin for the years 1912 to 1974. The Alameda and Rafferty Reservoirs were effectively two of these study points.

The SNBB computer model was modified by PFRA to carry out the simulation studies. Saskatchewan Environment developed estimates of current, foreseeable future and long-term future water demands for the entire Souris River basin in Saskatchewan.

Most importantly, the Souris River basin report evaluates a number of water supply projects in combination with flood damage reduction measures, presenting order-of-magnitude costs for each. Several specific recommendations were presented, together with a discussion of the benefits and impacts of individual proposals. The study identified the Rafferty and Alameda Reservoirs as technically feasible water storage sites.

1.3.3 Alameda Dam Studies

In the 1960's, PFRA identified the Alameda Dam on Moose Mountain Creek as a potential storage site. Field and office studies on this site are described in the PFRA report of May, 1976 (Ref.3).

Subsequent engineering studies in 1985 by Fennell, Cochrane, Lavalin Inc. (Ref.4), including a limited test drilling program, suggest that a larger reservoir than originally proposed at a revised location would provide a more effective water supply and flood control facility.

1.3.4 Saskatchewan Power Corporation (SPC)/Fennell, Cochrane, Lavalin Inc. (FCL) Studies of Rafferty Reservoir

A two-phase study of the proposed Rafferty Reservoir was completed for the SPC in 1984 (Ref. 5 and 6).

The Phase 1 report (Ref. 5), September 1983, established at the feasibility level the volumes of water that could be made available to supply future demands after present requirements and commitments are met. The report concludes that at present demand levels close to 8,500 cubic decametres (dam^3) of water supply would be available annually (firm supply) from Rafferty Reservoir.

FCL analyzed gross evaporation and precipitation values, updated the natural flow data to 1981 and provided estimates of water requirements for current, foreseeable future and long-term future demands in the basin. In complementing this work (this phase of the study), PFRA carried out several water supply simulation computer model runs. A subsequent Phase 2 study (Ref. 6) completed in 1985 also by FCL, examined a diversion channel from Long Creek (Boundary Reservoir) to Rafferty Reservoir, confirmed the technical feasibility of Rafferty Reservoir, and provided estimates of the costs of construction.

The study concluded that Rafferty Dam was feasible and that under normal flow conditions future water quality should be similar to that of other prairie lakes.

1.3.5 Sask Power Souris River Flood Study

This study (Ref. 4) conducted by FCL examined the technical feasibility, construction costs, water supply capability and flood reduction potential of the Alameda Reservoir. PFRA again carried out the water supply simulation modelling based on the input data provided by FCL.

The report detailed the flood peak reductions that would result both in Saskatchewan and at the international boundary from the construction of the Alameda Dam.

Flood reduction studies were undertaken and the results were provided as base information for studies being undertaken by the U.S. Army Corps of Engineers.

The study concluded that Alameda Dam is technically feasible and that additional amounts of water could be made available for irrigation in the basin from both reservoirs even if Rafferty supplies water for thermal power requirements and both reservoirs provide for foreseeable future uses in the basin.

1.3.6 Rafferty and Alameda Reservoirs Conceptual Evaluation of Irrigation and Recreation Costs and Benefits, Water Resource Consultants, December, 1985.

This study (Ref. 7) was commissioned by Sask Water to determine the potential for recreation and irrigation development in conjunction with the reservoirs. Five potential irrigation development scenarios were examined in detail and costs and benefits were determined for each. The study determined that land in the area could be feasibly irrigated from the reservoirs and that water based recreation facilities could be developed in conjunction with the irrigation developments at the reservoirs.

1.4 GENERAL APPROACH

The proposed reservoirs will be able to store water and make it available as required. To determine the change in hydrologic conditions as a result of this storage and release operation, the investigations were broken down into a water supply component and a flood control component. These two aspects require separation because they utilize different methodologies requiring different types of models and data.

Negotiations with the United States on the operating guidelines also were separated into a water supply component to deal with water sharing and a flood control component to develop the flood control operating guidelines. These components are discussed at a general level in sections 1.4.1 and 1.4.2.

1.4.1 Water Supply

The traditional approach to examine the hydrologic implications of a reservoir project to water supply involves the use of computer water balance models. By specifying precipitation, evaporation, water use data and reservoir storage characteristics in a computer water balance model, the impact of the proposed reservoir can be determined for any assumed set of flow conditions. For most applications the models are usually run with a historical set of streamflow data. The premise is that a sample of historical data of, say, greater than fifty years represents a best estimate of streamflow conditions in the future. It is not assumed that annual flow volumes will be repeated in the same sequence, but rather, that the range of flows, i.e. the frequency of extreme droughts and extreme floods, will likely be similar. Therefore, the average of the annual flow values in the next fifty years will be similar to the average flow over the last fifty years.

The measure of streamflow or water levels, i.e. reservoirs, that is generally used is the monthly mean natural flow/level. This quantity/level represents the average that would have occurred during that month at a particular location if there were no man made works to store, divert or consume the flow. These flow/level values generally have to be reconstructed by taking the recorded values in a month at a particular location and adding to them volumes of water that were consumed, stored or diverted upstream and subtracting from them, additional volumes of water added by drainage works.

The model can be used to simulate historic hydrologic conditions at any location by using the historic natural flows and historic use. The model would calculate, for each location, the volume of flow that would have been recorded during a particular month by subtracting out all of the upstream use.

The water balance model can be used to assess the change to the present hydrology by setting up the model with the natural flows and existing use and generating one set of simulated flow conditions without the project in the model and another set with the project in the model. The difference in the simulated flow conditions below the project location with and without the project would enable the impact from the project to be measured.

For this investigation the water balance model was used to determine the hydrologic conditions that would result from allocating water to various potential uses such as irrigation, thermal power plant cooling, etc.

The study by Water Resource Consultants (Ref. 7) showed, by the application of a water balance model, that given the historic flow situation that has occurred above the proposed Rafferty and Alameda Dam locations there is sufficient water for the cooling water requirements of the Shand generating station, economically establish irrigation on up to a maximum of 7,200 ha of land adjacent to and below the reservoirs, meet foreseeable future water requirements as defined in this study and meet Saskatchewan's obligations under the Interim Order of the IJC for apportionment of the flow of the Souris River basin. The study also showed that significant recreation benefits could be achieved and that by irrigating lesser amounts of land (less than 7,200 ha) the extremes in reservoir fluctuations could be reduced to complement recreation development. The hydrologic impact that could be produced as a result of meeting these demands with the proposed reservoirs in place is described in Chapters 3 and 4.

1.4.2 Flood Control

Reservoirs can be used to reduce peak flows/levels downstream by releasing water at a lesser rate than the peak inflow to the reservoir. This is accomplished by the reservoir temporarily storing water.

For flood studies the goal is to control large flows that are recognized as flood events. Historical flow data can be analyzed and a statistical assessment can be made that describes how often, on average, a specified flow/level could be expected to be exceeded in the future. These statistical assessments produce estimates of the probability of receiving a certain magnitude of flow or volume.

Flood flows/levels often centre around events that have a 1 percent chance of occurring in any year. These floods are described as 1:100 events. A less frequent flood, say one that has a 0.2 percent chance of occurring in any year (1:500) would normally have a larger total volume of flow and higher level (stage). By comparison, a 1:50 flood occurs, on average, twice as often as the 1:100 and it would have a flood peak and volume that would be less than the 1:100 flood.

For purposes of this study the focus has been on the ability of the reservoirs to reduce flooding resulting from all floods up to a 1:100 flood. The desire on the part of the United States is to be able to control/regulate the flows at Minot up to the 1:100 flood so as not to exceed the maximum capacity of their dyked channel through the city. This is to be accomplished by temporarily storing flood waters in Rafferty and Alameda Reservoirs in Saskatchewan, and Lake Darling in North Dakota, and then releasing water at a rate that will not contribute to flood damage through Saskatchewan or exceed channel capacities through Minot.

To develop the necessary operating guidelines, a computer model was used that can simulate flood conditions in the basin. Hydrographs were developed that represented a 1:50, 1:100 and 1:500 flood peaks and volumes and represented spring runoff. Through an iterative process, the model was then used to determine the operations required to achieve the flood control objectives as previously described. The manner in which floods can be controlled on the Souris River in Saskatchewan is described in detail in Chapters 3 and 4.

CHAPTER 2

PRE-PROJECT HYDROLOGY

(Existing Hydrology)

2.1 INTRODUCTION

2.1.1 General

The primary reason for describing the existing hydrological regime of the Souris River and Moose Mountain Creek (see Figure 2.1) is to enable a comparison with the hydrological regime caused by the proposed development. This comparison translates into the hydrologic impacts outlined in Chapter 4.

The climate, geology, geography and land use of a region determine the characteristics of the hydrological regime. The climatic factors having direct influence on the hydrological features of a region consist of the amount and distribution of precipitation, the occurrence of snow and ice and the effects of wind, temperature and humidity on evapotranspiration and snowmelt. The geology and geography of a basin account for the physical features of soil type, topography, basin and channel slopes, basin orientation and shape, and river morphology. These physical features determine factors such as infiltration, depressional storage, time of travel in streams, all of which influence the hydrograph shape for any given runoff event.

The existing hydrology is described in terms of maximum flows during prescribed flood events and monthly and annual flows or water levels at key locations in the basins.

2.1.2. Souris River Setting

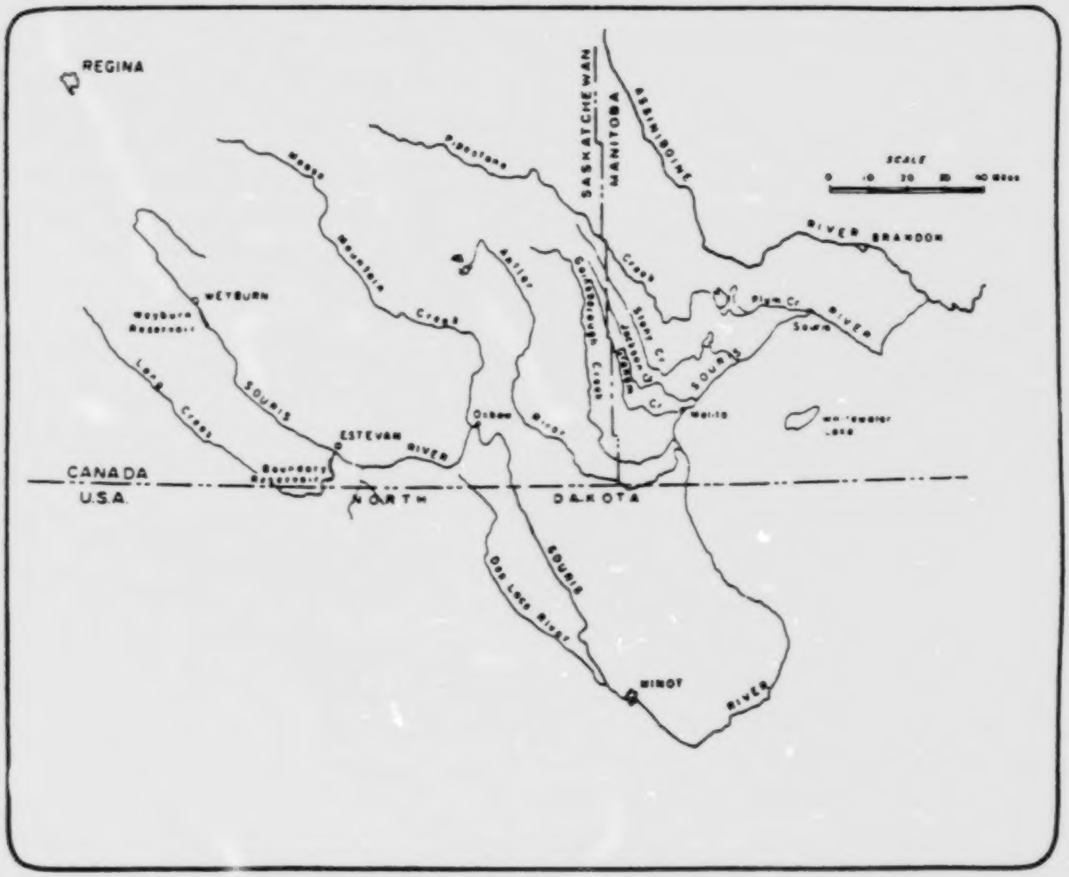
The Souris River rises in the flat Yellow Grass marshlands northwest of Weyburn. It flows in a general southeasterly direction for about 250 km, to the Canada-United States border where it enters North Dakota as shown on Figure 2.1. The river re-enters Canada in Manitoba where it joins the Assiniboine River and eventually discharges into Hudson's Bay.

The major tributaries of the Souris River within Saskatchewan are Long Creek which discharges into the Souris River downstream of the proposed Rafferty Dam site near Estevan and Moose Mountain Creek which joins the Souris farther downstream near Oxbow (see Figure 2.1).

The Souris River lies in a glacial valley cut into the Souris Plain between the uplands of the Missouri Coteau to the southwest and the hills around Moose Mountain to the north. The valley is some thirty metres deep and approximately one kilometre wide. The existing river channel meanders along the floor of the valley and is usually less than about twenty metres in width and two metres in depth.

Figure 2.1

LOCATION MAP OF THE SOURIS RIVER BASIN



2.1.3. Moose Mountain Creek Setting

Moose Mountain Creek is the major left-bank tributary of the Souris River. The headwaters of Moose Mountain Creek originate in the Strawberry and Chapleau Lakes area at an elevation of approximately 655 m above sea level. The Creek drains into the west and south facing slopes of the Moose Mountains, flowing into the Souris River near Oxbow at an elevation of 512 m. Oxbow is located about 30 km north of the North Dakota border and 60 km west of the Manitoba border.

Moose Mountain Creek is located on the edge of a glacial lake plain but partially in a glacial melt-water channel. The soils near the creek are generally sandy loam over gravel, while the uplands are a loamy textured till on an undulating till plain. Near Kisbey there is a concentration of eskers. The average gradient of Moose Mountain Creek in the lower reaches of the sub-basin (downstream of Arcola) is 1.80 m/km while in the upper reaches it is about 0.45 m/km. By contrast the Souris River just upstream of Oxbow is entrenched in a glacial valley and meanders with an average gradient of about 0.15 m/km. The valley at the proposed Alameda Dam site has an open "V" shape, with no natural tree growth along its periphery. The uplands on both sides are approximately 30 m above the valley bottom and contain numerous undrained depressions typical of ground moraines.

2.1.4 Drainage Areas

The area contributing to surface run-off in drainage basins subject to glacial transformation as found in the prairies can be difficult to determine. This has led prairie hydrologists to define the following terms:

- The effective drainage area is that area which might conceivably contribute to peak flow in a median year. Marshes and sloughs with no connecting channel to the stream are excluded.

- The gross drainage area is that area enclosed within its divide (height of land) which would contribute to the flood peak under extremely wet conditions.

These drainage areas for the Moose Mountain Creek sub-basin are summarized in Table 2.1.

TABLE 2.1

GROSS AND EFFECTIVE DRAINAGE AREAS SOURIS RIVER BASIN

Hydrometric Station	Drainage Area (km^2) Gross	Effective
Souris River at Weyburn	2,242	860
Long Creek near Estevan	4,842	1,488
Souris River near Estevan	11,287	4,025
Moose Mountain Creek below Moose Mountain Lake	2,306	772
Moose Mountain Creek at Proposed Alameda Dam Site	5,325	1,990
Moose Mountain Creek near Oxbow	6,051	2,163
Souris River near Oxbow	21,955	7,049
Souris River near Sherwood	22,360	7,370

Source: Hydrology Report #104, PFRA, January, 1985

2.2 EXISTING WATER USE

2.2.1 Introduction

Natural flows in the Souris River and Moose Mountain Creek have been altered over time through demands placed on the water. Water demands include not only consumptive use of the river flows such as water supply for municipal, industrial, thermal power generation and agricultural uses but also for non-consumptive demands by aquatic wildlife (fish, waterfowl, etc.), as well as by humans for water-based recreation and the aesthetic values of aquatic settings. In addition, natural flows have been altered by return flows to the river from municipal sewage treatment plants and from irrigation, as well as by the development of artificial drainage works.

The most significant of the current water demands in the Souris River basin is the commitment to meet the requirements for apportionment of the water with the United States. In simplified form, this requires one-half of the runoff originating as natural flow.

2.2.2 Consumptive Use

Table 2.2 summarizes the licensed water uses in the effective drainage area of the Souris River basin.

TABLE 2.2

SUMMARY OF LICENSED WATER USES - 1985 (dam^3)$^{1)}$

Located in the Effective Drainage Area
Souris River Basin

Purpose of Use	Location				
	Souris River Above Weyburn Dam	Souris River Weyburn Dam to Rafferty Dam	Long Creek Sub-Basin	Moose Mountain Creek Sub-Basin	Souris River Rafferty Dam to USA Border
Domestic	75	695	287	234	174
Municipal	3,207	84	2,378	850	1,690
Industrial	-	-	9,000*	-	240
Irrigation**	345	1,248	523	449	879
Other	-	4	64	1,718	40
Multi-Purposes	-	1,162	-	1,172	-
TOTAL	3,627	3,193	12,252	4,423	3,023

* The estimated uses are 6500 dam^3 for forced evaporation and 2500 dam^3 for natural evaporation. The licensed allocation is 3562 dam^3.

** Represents irrigation of an estimated 1500 ha.

1) Abstracted from Sask Water licensing information.

The City of Estevan, has a licensed annual diversion of 3,096 dam^3; actual pumpage in 1985 was 2,060 dam^3. Estevan no longer draws its water supply from the Souris River but conveys it by pipeline (since 1985) from Boundary Reservoir. Former intakes on the Souris River have been retained for emergency use only.

The City of Weyburn draws its municipal water supply from the Albert Douglas Reservoir; licensed annual diversion is 2960 dam^3. By comparison, the actual pumpage volume in 1985 was 1,770 dam^3.

Municipal water demand in both Estevan and Weyburn varies from month to month. The monthly distributions of consumption for 1980 and 1981 are shown on Figure 2.2 as well as the average monthly distributions of water consumption expressed as a percentage of annual consumption.

The historical trend in total annual water demand for the City of Estevan for the period from 1960 to 1981 is shown on Figure 2.3. It can be seen that the trend is uniform and allows for projections of future municipal usage.

Table 2.2 includes information on current licensed water users within the Moose Mountain Creek sub-basin. Here, municipal water use is quite minor with the Town of Arcola, the regional municipality of Golden West and the villages of Creelman and Montmartre diverting a total of 850 dam^3 annually. The largest single water demand is at Moose Mountain Lake, which was constructed by Saskatchewan Agriculture for irrigation and stock watering purposes.

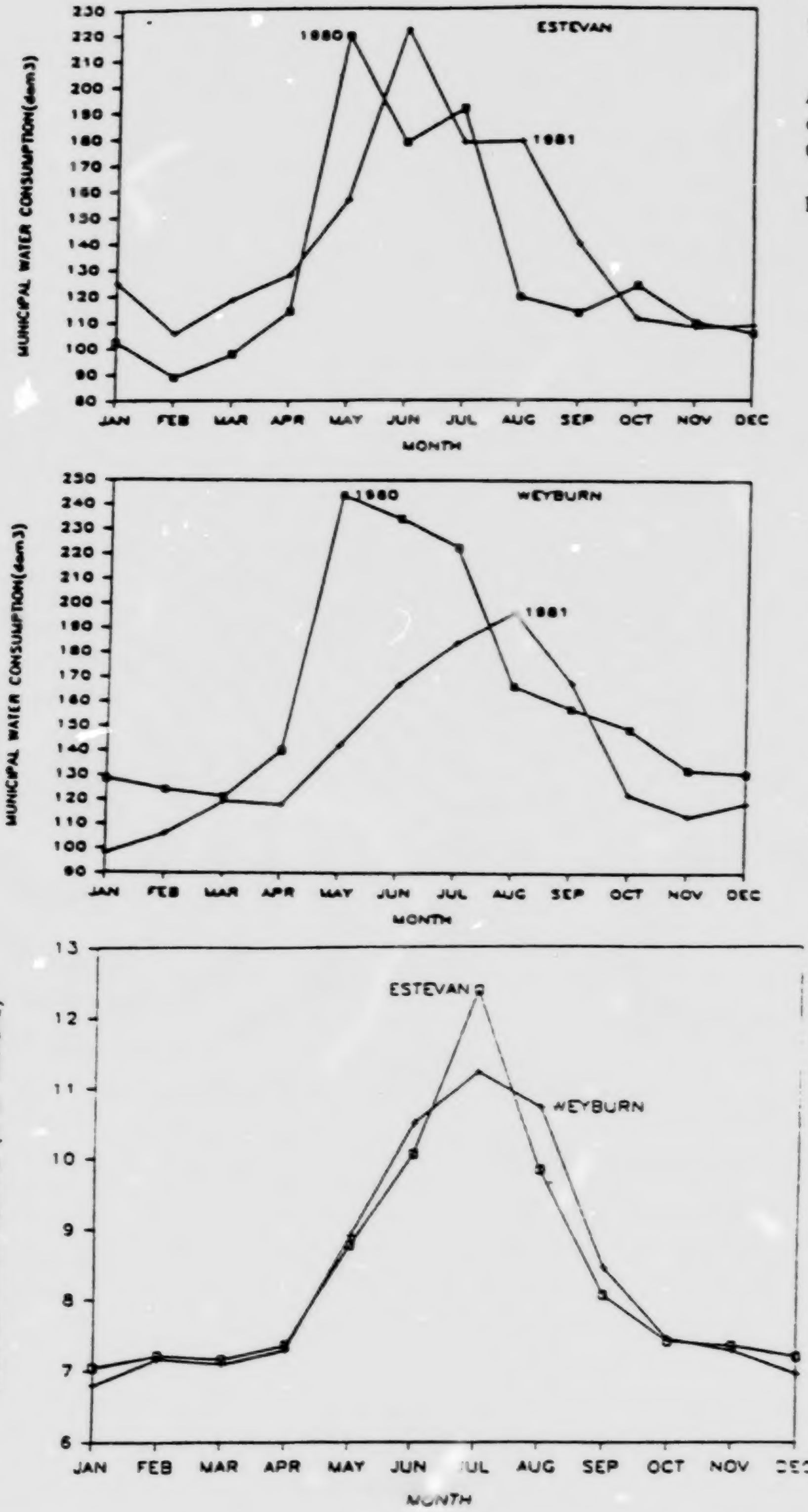


Figure 2.2

Annual Distribution of Municipal Water Consumption

Estevan & Weyburn

Source: Fennell Cochrane Lavalin (1983)

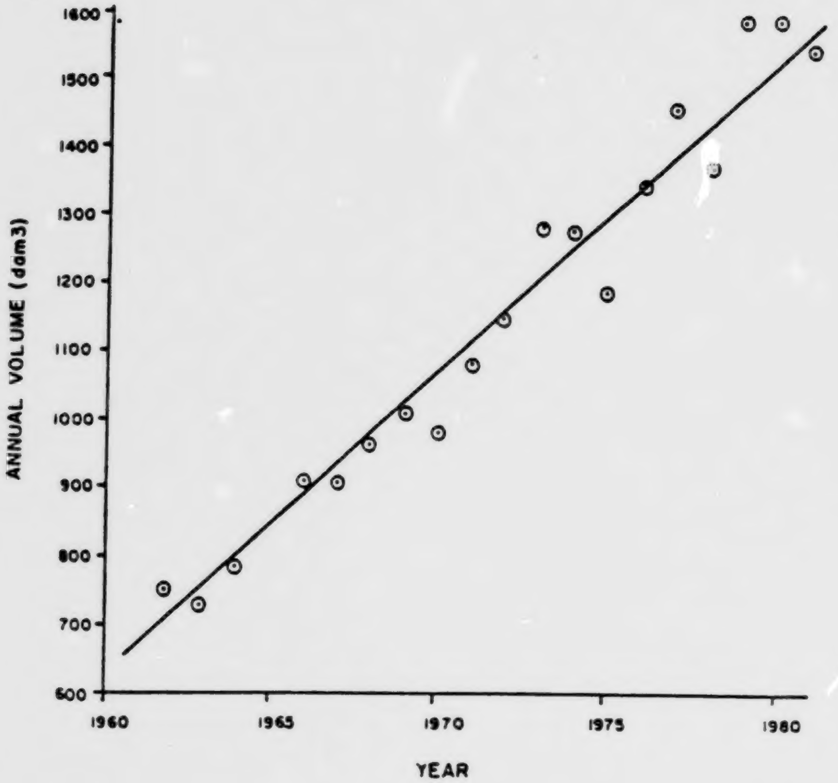


Figure 2.3

Historical Trend
Annual Water
Demand

Estevan

Source: Fennell
Cochrane Lavalin
(1983)

2.2.3 Discharges

Municipal Effluent

Both Estevan and Weyburn discharge their treated effluent into the Souris River and both municipalities follow the pattern of releasing effluent from lagoon storage twice yearly. The timing of the discharges is dependent on the capacity of the lagoon and, to a lesser extent, on the prevailing flows in the Souris River. Typically, effluent discharge occurs in the spring -- late March and April and in the fall during October. During these periods dispersion and dilution of the effluent is not hampered by ice conditions in the river. The rate of effluent discharge is adjusted to maintain a constant flow over the period of release. The amount of effluent varies but typical recent quantities are shown in Table 2.3.

TABLE 2.3

MUNICIPAL EFFLUENT DISCHARGE

	1985 (dam^3)		1986 (dam^3)
ESTEVAN			
Spring -			
(early March)	50		
(Mar. 22 - Apr. 4)	250	(Apr. 11 - May 2)	441
Fall -			
(Sept. 22 - Oct. 18)	345	(Oct. 16 - Nov. 10)	441
Total -	645		882
WEYBURN			
Spring -			
(Apr. 2 - May 3)	731		
Fall -			
(Oct. 2 - 31)	263		
Total -	994		

Source: Saskatchewan Environment

Drainage

The Yellow Grass marsh is the only organized land drainage scheme that has significantly affected flows in the Souris River. These effects, both in peak discharge and volume, diminish with distance downstream.

Drainage increases the rate and shortens the period of local runoff from drained lands. Drains can also increase the volume of runoff by reducing the potential storage available in natural retention areas such as sloughs and depressions. These effects were studied as part of the Souris River Basin Study when it was estimated that the natural contributing drainage area upstream of the Yellow Grass Marsh outlet had been increased from 572 km^2 to 1,155 km^2 (1976). The flood peaks were calculated for both natural and 1976 conditions.

The volume of runoff from the Yellow Grass marsh was also estimated for the natural and 1976 development conditions as shown in Table 2.4.

TABLE 2.4

VOLUME OF RUNOFF FROM YELLOW GRASS MARSH

Return Period in Years	Volume of Runoff in Acre-Feet Natural	1976 Condition	Increase	Percent Increase
2	0	4,800	4,800	-
10	20,500	33,000	12,500	61
25	36,600	51,000	14,400	40
50	51,000	66,000	15,000	29
100	66,000	82,000	16,000	24
500	101,000	120,000	19,000	19

Source: From Souris River Basin Study Report - 1978.

2.2.4 Apportionment

The largest single water use in the basin is represented by the annual volume of water that Saskatchewan must pass to North Dakota on the Souris River. This annual volume is referred to as an apportionment of the Souris River and must conform to the terms established by the International Joint Commission and referred to as the "1959 Interim Measures". These measures are as follows:

1. The Province of Saskatchewan shall have the right to divert, store and use waters which originate in the Saskatchewan portion of the Souris River basin, provided that such diversion, storage and use shall not diminish the annual flow of the river at the Sherwood Crossing more than fifty percent of that which would have occurred in a state of nature. For the benefit of riparian users of water between the Sherwood Crossing and the upstream end of Lake Darling, the Province of Saskatchewan shall so far as practicable regulate its diversions,

Sherwood Crossing and the upstream end of Lake Darling, the Province of Saskatchewan shall so far as practicable regulate its diversions, storage and uses in such manner that the flow in the Souris River channel at the Sherwood Crossing shall not be less than four (4) cubic feet per second when that much flow would have occurred under the conditions of water use development prevailing in the Saskatchewan portion of the Souris River basin prior to construction of the Long Creek dam referred to in paragraphs 12 and 14 above.

2. Except as otherwise provided herein with respect to delivery of water to the Province of Manitoba, the State of North Dakota shall have the right to divert, store and use the waters which originate in the North Dakota portion of the Souris River basin together with the waters delivered to the State of North Dakota at the Sherwood Crossing under Recommendation (1) above; provided that any diversion, use or storage of Long Creek water shall not diminish the annual flow at the eastern crossing of Long Creek into Saskatchewan below the annual flow of said Creek at the western crossing into North Dakota.

3. (a) In addition to the waters of the Souris River basin which originate in the Province of Manitoba, that Province shall have the right, except during periods of severe droughts, to receive for its own use and the State of North Dakota shall deliver from any available source during the months of June, July, August, September and October of each year, six thousand and sixty-nine (6,069) acre-feet of water at the Westhope Crossing regulated so far as practicable at the rate of twenty (20) cubic feet per second except as set forth hereinafter: provided, that in delivering such water to Manitoba no account shall be taken of water crossing the boundary at a rate in excess of the said 20 cubic feet per second.

3. (b) In periods of severe drought when it becomes impracticable for the State of North Dakota to provide the foregoing regulated flows, the responsibility of the State of North Dakota in this connection shall be limited to the provision of such flows as may be practicable,

in the opinion of the said Board of Control, in accordance with the objective of making water available for human and livestock consumption and for household use. It is understood that in the circumstances contemplated in this paragraph the State of North Dakota will give the earliest possible advice to the International Souris River Board of Control with respect to the onset of severe drought conditions.

4. In event of disagreement between the two sections of the International Souris Board of Control, the matters in controversy shall be referred to the Commission for decision.

5. The interim measures for which provision is herein made shall remain in effect until the adoption of permanent measures in accordance with the requirements of questions (1) and (2) of the Reference of January 15, 1940, unless before that time, these interim measures are qualified or modified by the Commission.

2.3 EXISTING HYDROLOGIC REGIME

2.3.1 Hydrometric and Climatic Data Collection

2.3.1.1 General

The collection and distribution of hydrologic data in the Souris River basin involves at least thirteen government agencies in Canada and the United States. The hydrometeorologic network is vital to the successful operation of the existing system which involves significant storage in Albert Douglas, Moose Mountain and Boundary Reservoirs in Canada and Lake Darling in the United States. This network must be maintained to ensure that adequate data are provided and it must be modified from time to time as required to improve the forecasting of runoff volumes and stream flow/water levels and to serve in making decisions on operations.

In Canada, the federal government through the Water Resources Branch of of hydrometric stations to record stream flow and water levels while the Atmospheric Environment Service, Environment Canada, maintains and operates a network of meterological stations. In addition, the Saskatchewan Water Corporation operates a number of snow courses in the basin. The purpose of the snow course measurements is to provide additional data for forecasting spring runoff.

In the United States, the United States Geological Survey is responsible for maintaining and operating a network of hydrometric stations to record stream flow/water levels, while the United States Weather Bureau operates and maintains a network of meteorological stations. These are both federal agencies. The United States Weather Bureau also undertakes aerial gamma surveys to provide additional snow data for forecasting spring runoff.

A list of the stations and types of data collected from the existing hydrometric station networks in Canada and in the United States is shown in Tables 2.5 and 2.6, respectively.

The existing meteorological network for Canada, exclusive of snow courses, is shown in Table 2.7.

2.3.1.2 Climate

General climatological mapping of the prairies indicates that Estevan and the Souris River Valley, including the proposed Rafferty Reservoir area, are located within a homogeneous climatic region. It can be described as semi-arid continental, typified by extreme variations in both temperature and precipitation.

Precipitation data have been recorded at Estevan since 1912. Figure 2.4 shows the mean monthly variation from a low of 15 mm in February to a high of 75 mm in June. The majority (56 percent) of the mean annual precipitation of 374 mm[1] falls within the four-month period from May through August.

Annual precipitation of 408 mm at Oxbow varies from a mean monthly low of about 17 mm in January to a mean monthly high of about 69 mm in June. The majority (55 percent) of the annual precipitation at Oxbow falls within the four-month period from May through August. However, it is by no means distributed evenly. The largest 24-hour rainfall during 30 years of record is 104.1 mm, or 25.5 percent of the annual average. Storms causing this kind of rainfall can occur when warm, moist air moving north from the United States meets a cold front.

Although most of the annual precipitation falls during the summer months, very little rainfall contributes to stream flow. The majority either infiltrates to reduce the soil moisture deficit, or it is lost to evaporation from sloughs and lakes, or to plant evapotranspiration. However, snowmelt contributes significantly to stream flow. In southern Saskatchewan up to 85 percent of annual runoff can be attributed to snowmelt.

In the study area, annual evaporation can greatly exceed annual precipitation. In 1972 the SNBB estimated the mean annual gross evaporation from shallow lakes and reservoirs in the Moose Mountain Creek sub-basin to be 700 mm. However, other approaches have yielded even higher values for gross evaporation. Christiansen[2] used a climatological approach to data from 1957-1966 and estimated the open water gross evaporation for Moose Mountain Lake to be 842 mm. This would give an annual net evaporation of about 484 mm, which agrees with net natural evaporation of 457 mm for Boundary Reservoir as calculated by Saskatchewan Environment.

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[1] FCL - 1912 - 1981 inclusive.

[2] Estimating Evaporation and Evapotranspiration from Climatic Data-Christiansen, J.E., 1966.

TABLE 2.5

HYDROMETRIC STATION NETWORK FOR SOURIS BASIN IN SASKATCHEWAN

Station No.	Station Name	Location		Type
		Latitude	Longitude	
05NA003	Long Creek at Western Crossing	49°00'01"	103°21'08"	Flow; auto recorder; telemark
05NA004	Long Creek near Maxim	49°15'32"	103°57'22"	Flow; auto recorder; seasonal
05NA005	Gibson Creek near Radville	49°29'02"	104°20'11"	Flow; auto recorder; seasonal
05NA006	Larsen Reservoir near Radville	49°28'30"	104°16'50"	Water level; auto recorder
05NB001	Long Creek near Estevan	49°06'15"	103°00'48"	Flow; auto recorder
05NB009	Souris River near Roche Percee	49°04'34"	102°45'53"	Flow; auto recorder
05NB011	Yellow Grass ditch near Yellow Grass	49°47'11"	104°02'16"	Flow; auto recorder; seasonal
05NB012	Boundary Reservoir near Estevan	49°05'49"	103°01'28"	Water level; auto recorder
05NB014	Jewel Creek near Goodwater	49°23'10"	103°42'42"	Flow; auto recorder; seasonal
05NB016	Roughbar Reservoir near Weyburn	49°30'08"	103°43'07"	Water level; auto recorder
05NB017	Souris River near Halbrite	49°29'37"	103°39'44"	Flow; auto recorder; seasonal
05NB018	Tatagwa Lake Drain near Weyburn	49°35'58"	103°56'50"	Flow; auto recorder; seasonal
05NB020	Nickle Lake near Weyburn	49°34'32"	103°46'08"	Water level; auto recorder
05NB021	Short Creek near Roche Percee	49°01'52"	102°50'57"	Flow; auto recorder
05NB022	Dead Lake Reservoir near Midale	49°17'23"	103°26'40"	Water level; auto recorder
05NB025	Souris River near Lewvan	49°58'37"	104°04'33"	Flow; auto recorder; seasonal
05NB029	Dead Lake - Souris River	49°17'23"	103°26'40"	Water level; auto recorder
05NB030	Souris River near McTaggart	49°46'10"	104°00'56"	Flow; auto recorder; seasonal
05NB031	Souris River near Bechard	49°59'20"	104°11'24"	Flow; auto recorder; seasonal
05NC001	Moose Mountain Creek below Moose Mountain Lake	49°52'23"	103°00'54"	Flow, auto recorder; seasonal
05NC002	Moose Mountain Res.	49°53'29"	103°01'58"	Water level; auto recorder
05ND001	Souris River near Glen Ewen	49°11'02"	102°01'42"	Flow, auto recorder
05ND004	Moose Mountain Creek near Oxbow	49°13'58"	102°13'41"	Flow; auto recorder; seasonal
05NF006	Lightning Creek near Carnduff	49°13'17"	101°43'08"	Flow; auto recorder; seasonal
05NF010	Antler River near Wauchope	49°35'03"	101°50'52"	Flow; auto recorder; seasonal
05NF013	Gainsborough Creek near Storthoaks	49°24'51"	101°31'36"	Flow; auto recorder; seasonal
24-131 *	Souris River at #18 Highway	49°07'42"	103°01'17"	Flow; auto recorder; Extreme flow only
24-132 *	Souris River at # 47 Highway	49°07'11"	102°59'32"	Flow; auto recorder Extreme flow only
24-133	Souris River at Oxbow	49°13'04"	102°11'08"	Flow; auto recorder Extreme flow only
	Souris River at Pulfer's Farm	INFORMATION NOT AVAILABLE		

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* These stations have not been monitored regularly. Information has not been checked by Sask. Water and should be used with discretion.

TABLE 2.6

HYDROMETRIC STATION NETWORK FOR SOURIS BASIN IN NORTH DAKOTA

Station No.	Station Name	Location		Type
		Latitude	Longitude	
05114000	Souris River near Sherwood N.D.	48°59'24"	101°57'28"	Flow; auto recorder telemark
05115500	Lake Darling near Foxholm	48°27'27"	101°35'14"	Water level; auto recorder
05116000	Souris River near Foxholm	48°22'20"	101°30'18"	Flow; auto recorder; telemark
05116500	Des Lacs River near Foxholm	48°22'14"	101°34'11"	Flow; auto recorder
05117500	Souris River above Minot	48°14'45"	101°22'15"	Flow; auto recorder; telemark
05120000	Souris River near Verendrye	48°09'35"	100°43'45"	Flow; auto recorder
05120500	Wintering River near Karlsruhe	48°10'14"	100°32'20"	Flow; auto recorder
05122000	Souris River near Bantry	48°30'20"	100°26'04"	Flow; auto recorder; telemark
05123000	Lake Metigoshe near Bottineau	48°59'05"	100°20'52"	Water level; auto recorder
05123400	Willow Creek near Willow City	48°35'20"	100°26'30"	Flow; auto recorder
05123510	Deep River near Upham	48°35'03"	100°51'44"	Flow; auto recorder; telemark
05123900	Boundary Creek near Landa	48°48'46"	100°51'46"	Flow; auto recorder
05124000	Souris River near Westhope	48°59'47"	100°57'29"	Flow; auto recorder

TABLE 2.7

METEOROLOGICAL STATION NETWORK FOR SOURIS BASIN IN SASKATCHEWAN

Station Name	Station	Location		Observing Programme*									
		Latitude	Longitude	TE	PR	HW	RR	ST	EV	SU	SS	NS	WS
Alameda		49° 24'	102° 16'								X		
Amulet	4010150	49° 37'	104° 44'	X	X								
Arcola CDA	4010240	49° 38'	102° 32'		X								
Bechard	4010540	50° 03'	104° 13'	X	X								
Broadview	4010879	50° 23'	102° 35'	X	X	X	X	X	X	X	X	X	
Carlyle	4011160	49° 38'	102° 17'	X	X								
Carlyle		49° 39'	102° 16'								X		
Carlyle C-7		49° 39'	102° 20'								X		
Carnduff	4011250	49° 13'	101° 45'		X								
Ceylon	4011441	49° 24'	104° 39'	X	X								
Davin 3	4012162	50° 24'	104° 11'		X								
Davin 6	4012165	50° 22'	104° 09'		X								
Davin 7	4012166	50° 23'	104° 10'	X	X		X		X				
Estevan		49° 05'	102° 59'								X		
Estevan A	4012400	49° 04'	103° 00'	X	X	X	X	X	X	X	X	X	
Estevan C-9		49° 08'	102° 56'								X		
Fertile	4012485	49° 20'	101° 27'	X	X								
Fleming S.	4012525	50° 02'	101° 35'		X								
Francis	4012720	50° 07'	103° 55'	X	X								
Frobisher		49° 13'	102° 09'								X		
Gainsborough	4012790	49° 18'	101° 32'		X								
Glenavon		50° 12'	103° 08'								X		
Handsworth	4013098	49° 51'	102° 52'	X	X								
Handsworth		49° 53'	103° 02'								X		
Heward	4013221	49° 45'	103° 09'	X	X								
Hitchcock		49° 15'	103° 10'								X		
Hume		49° 40'	103° 37'								X		
Indian Head CDA	4013480	50° 32'	103° 40'	X	X			X				X	
Indian Head PFRA	4013490	50° 31'	103° 41'	X	X			X	X	X			X
Kipling	4014040	50° 12'	102° 44'	X	X								
Kisbey		49° 40'	102° 45'								X		
Macoun	4014870	49° 14'	103° 14'		X								
Maryfield	4015045	49° 50'	101° 32'	X	X								
Maxim		49° 19'	103° 57'								X		
Midale	4015160	49° 24'	103° 25'	X	X								
Moose Mountain Reservoir	4015344	49° 53'	103° 02	X	X				X				
Moosomin	4015360	50° 09'	101° 40'	X	X								
Neptune		49° 22'	104° 06'								X		
Neptune S.		49° 19'	104° 02'								X		
Noonan N.D.		48° 57'	103° 03'								X		
Odessa	4015648	50° 20'	103° 41'	X	X								
Oungre		49° 09'	103° 45'								X		
Oxbow	4015800	49° 19'	102° 07'	X	X								
Oxbow		49° 14'	102° 07'								X		
Radville CDA	4016400	49° 30'	104° 17'			X							
Redvers	4016522	49° 32'	101° 42'	X	X								
Torquay	4018105	49° 05'	103° 30'		X								
Trossachs N.E.		49° 36'	104° 11'								X		
Trossachs S.		49° 34'	104° 17'								X		
Wapella - Newfinland	4018508	50° 27'	101° 56'	X	X								
Wawota	4018678	49° 56'	101° 58'	X	X								
Weyburn	4018760	49° 39'	103° 50'	X	X			X	X	X			X
Weyburn		49° 40'	103° 53'								X		
Weyburn 2	4018762	49° 40'	103° 51'		X								
Willmar	4018960	49° 25'	102° 30'		X								
Yellow Grass	4019040	49° 48'	104° 10'	X	X								

*TE - Temperature
PR - Precipitation
HW - Hourly Weather
RR - Rate of Rainfall

ST - Soil Temperature
EV - Evaporation
SU - Sunshine

SS - Snow Survey
NS - Nipher Snow Measurements
WS - Windspeed

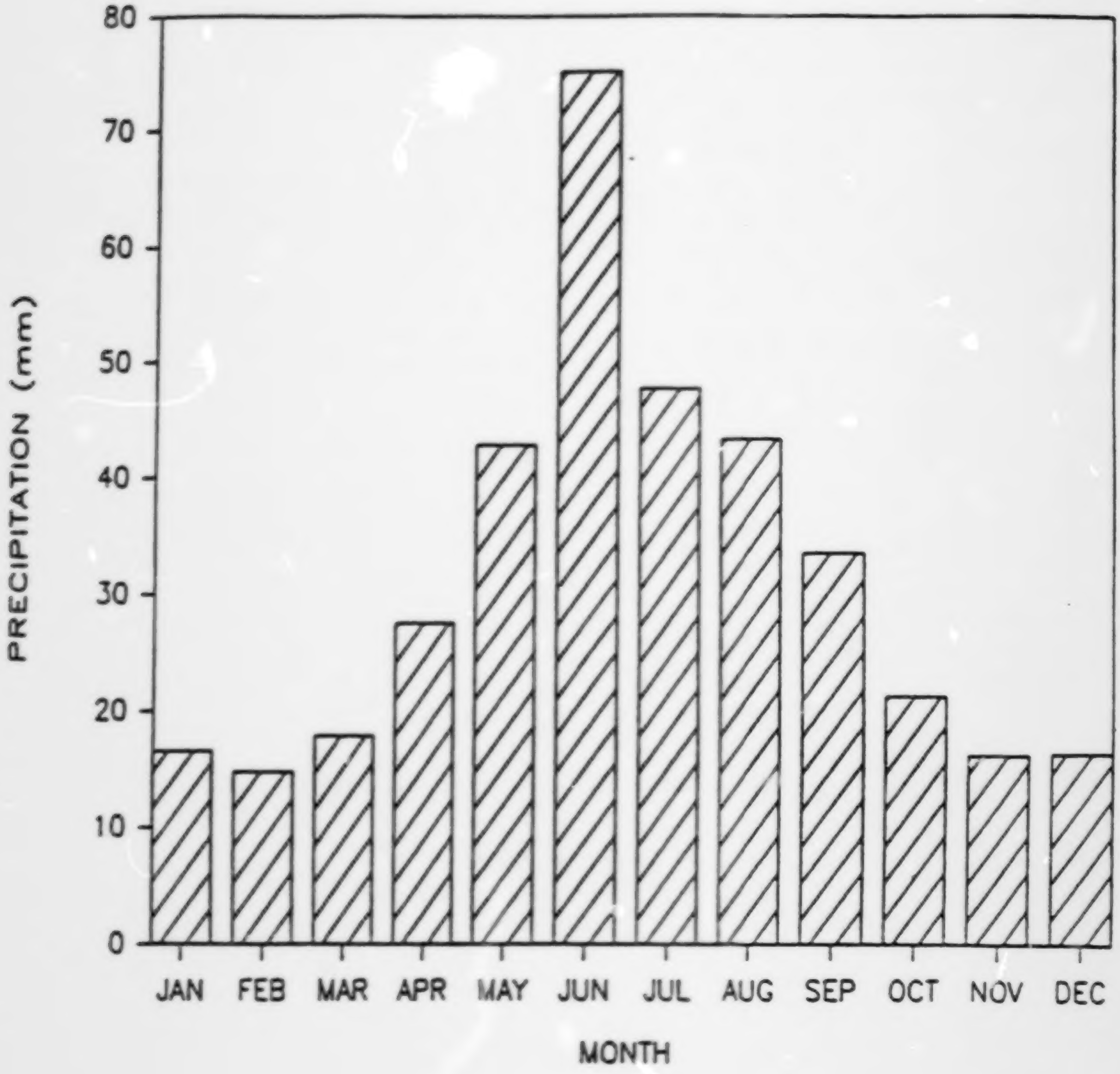


Figure 2.4 MEAN MONTHLY VARIATION
OF PRECIPITATION
AT ESTEVAN

Source: PFRA (1982)

Evapotranspiration includes water leaving moist soils by evaporation and water passing through plant tissue by transpiration. The average potential evapotranspiration in the study area (1921-1950 data) is 550 mm. Using the Oxbow mean annual precipitation of 408 mm, this gives an average soil moisture deficit of 142 mm.

The average amount of bright sunshine at Estevan, based on 30 years of record, is 2,537 hours per year. This is the greatest number of hours of bright sunshine recorded at any Class I meteorological station in Saskatchewan.

The maximum recorded hourly wind speed at Estevan was 90 km/hr and the maximum gust was 137 km/s. The 1:100 hourly wind speed calculated from the Estevan data is 104 km/hr.

2.3.2 Existing Works

A number of natural lakes and man-made reservoirs are located in the Souris River basin. None of the natural lakes contribute significantly to basin water supplies but most provide other benefits to the area. Kenosee and White Bear Lakes are extensively utilized as recreation areas. Tatagwa Lake in the upper Souris River basin and numerous smaller lakes in the Moose Mountain sub-basin provide valuable waterfowl staging and nesting areas.

A number of water supply sources have been developed on the Souris River mainstem and on the tributaries. The major projects are listed in Table 2.8 and shown on Figure 2.5. Of these developments, Boundary Reservoir on Long Creek is the most important for water supply. It supplies cooling water for the Boundary thermal generating station and municipal water for the city of Estevan. The Albert Douglas Reservoir (formerly Weyburn Reservoir) serves as a municipal water source for the City of Weyburn. Moose Mountain Reservoir, another man-made facility on Moose Mountain Creek, was constructed in 1937 for stock watering and irrigation.

As described earlier under "Drainage", there are extensive agricultural drainage works in the upper Souris River basin, upstream of the City of Weyburn, as well as improvements to the outlet from Tatagwa marsh. The Deveron-Glenavon flood control project is the only group drainage development in the Moose Mountain Creek sub-basin. It increased the effective drainage area by about 10 km^2.

TABLE 2.8

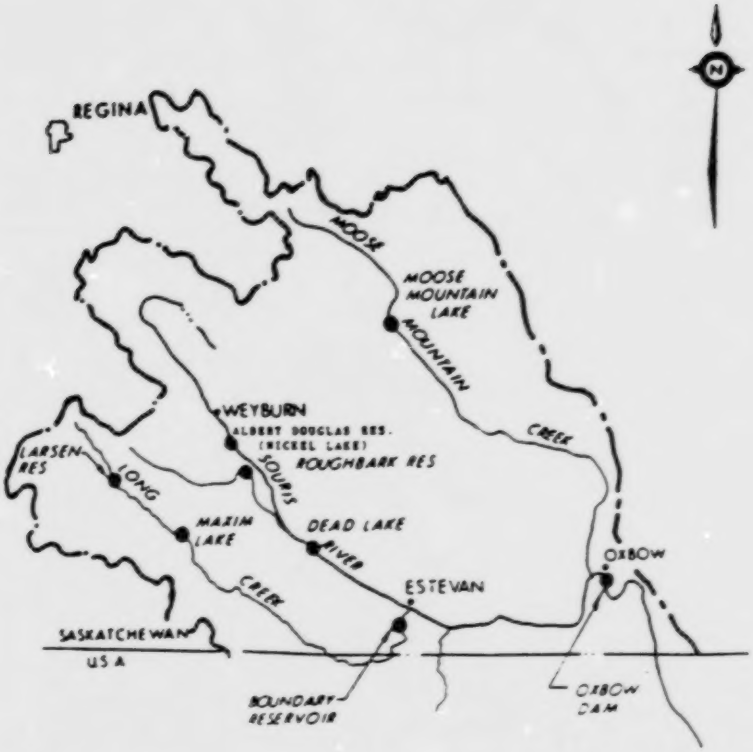
MAJOR WATER DEVELOPMENT PROJECTS EXISTING IN THE STUDY AREA

Project	Year Constructed	Water Source	Storage Capacity (dam^3)	Principal Purpose
Albert Douglas Res. (Weyburn Reservoir)	1983	Souris River	16,000*	Municipal Water Supply
Roughbark Reservoir	1937	Roughbark Creek	2,100	Stockwatering and Irrigation
Dead Lake	1937	Souris River	6,900	Stockwatering and Irrigation
Maxim Lake	1949	Long Creek	2,700	Stockwatering
Larsen Reservoir	1957	Long Creek	800	Municipal Water Supply
Boundary Reservoir	1958	Long Creek	60,600	Cooling Water for Electric Generation and Municipal Water Supply
Moose Mountain Lake	1937	Moose Mountain Creek	11,600	Stockwatering and Irrigation
Oxbow Dam	1960	Souris River	400	Recreation and Irrigation

* Enlarged in 1983 from 6,300 dam^3.

Figure 2.5
Map Showing
Major Projects

Souris River Basin
in Saskatchewan



2.3.3 Existing Flow Conditions

2.3.3.1 Souris River

Because of the limitations on available surface water in southern Saskatchewan there is a relatively high density of stream flow/water level gauging stations in the project area. Currently, there are some 33 stations located south and east of Moose Jaw. Some of these stations were established as early as 1910, while others came into operation as recently as 1973. The stream flow monitoring system is mainly operated by Water Resources Branch, Environment Canada, and the United States Geological Survey (USGS). The Saskatchewan Water Corporation also maintains several stream flow gauges in the area, primarily to monitor spring runoff.

Ice conditions, particularly in the smaller channels, frequently interfere with the stage-discharge relationships used to estimate stream flows. Thus, many of the stations are seasonal and are operated only from March through October. During the winter, very low discharges tend to occur naturally in the rivers and most of the smaller streams freeze completely.

Although the bulk of the annual precipitation falls as rain during the summer months, most of the rainfall is either quickly absorbed by the soil or is lost by evapotranspiration. Direct runoff in the summer months is low. The mean total rainfall in June, July and August at Estevan is about 167 mm; the mean natural stream flow at Rafferty for those three months is 0.5 m^3/s[3]. With the effective drainage area upstream of Rafferty being 2,420 km^2, less than 2 mm of rainfall actually contributes directly to surface runoff. This indicates a very low runoff co-efficient for the summer months.

Summaries of the recorded monthly stream flow for two WSC gauging stations on the Souris River, one at Roche Percee (Station No. 05NB009) and the other at Sherwood (Station No. 05ND007), are shown on Figures 2.6 and 2.7, respectively. These records typify the existing flow regime on the Souris River and highlight the extreme variations in flow, not only from month to month but from year to year. For example, the flows on the Souris River near Sherwood for the period of record 1931-76 reflect an annual range from a minimum of 1,400 dam^3 (1937) to a maximum of 776,000 dam^3 (1976). The mean volume for that period was 125,000 dam^3 with 82 percent occurring during the spring period (March - May).

2.3.3.2. Moose Mountain Creek

The Water Resources Branch, Environment Canada, has established the following stream-flow stations on Moose Mountain Creek.

- Moose Mountain Creek near Glenavon (05NC005);
- Moose Mountain Creek below Moose Mountain Lake (05NC001);
- Moose Mountain Creek above Kisbey Irrigation Project (05NC003);
- Moose Mountain Creek below Kisbey Irrigation Project (05NC004); and,
- Moose Mountain Creek near Oxbow (05ND004).

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[3] Phase I Report - Rafferty Reservoir Multi-Use Feasibility Study Volume I, Main Report, Fennel, Cochrane, Lavalin, September, 1983.

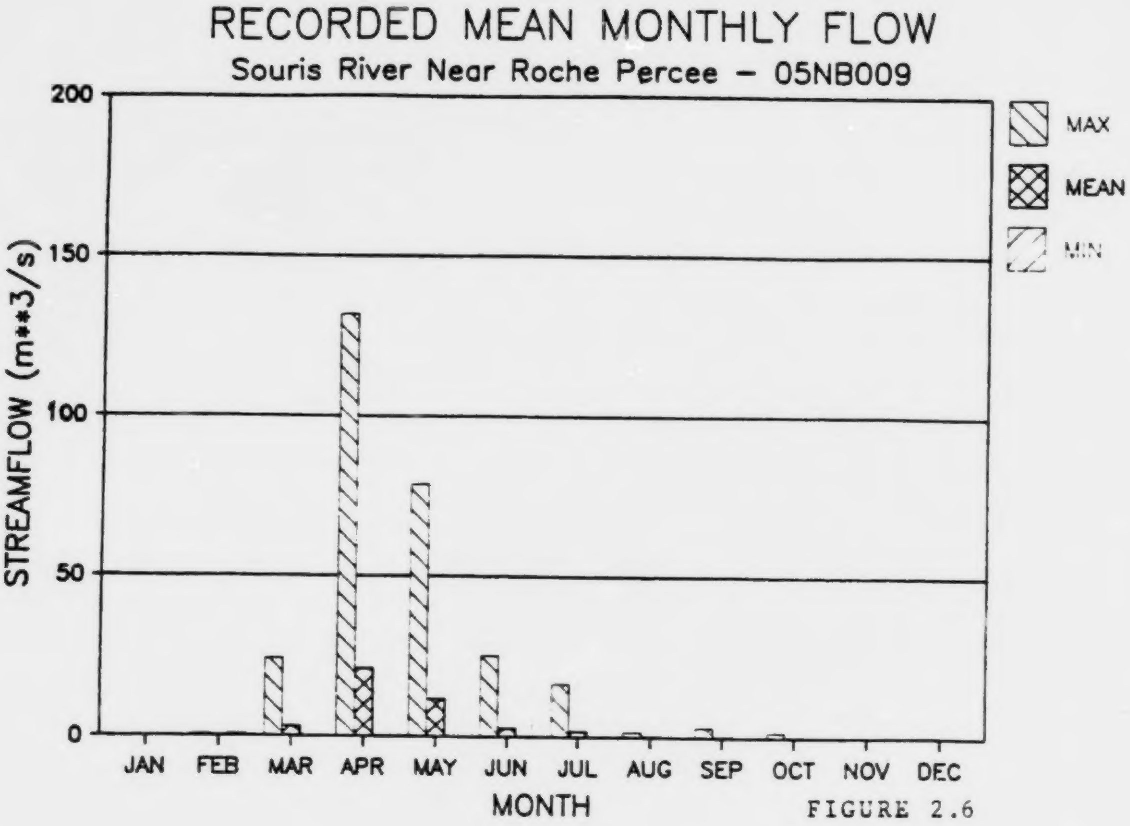

FIGURE 2.6

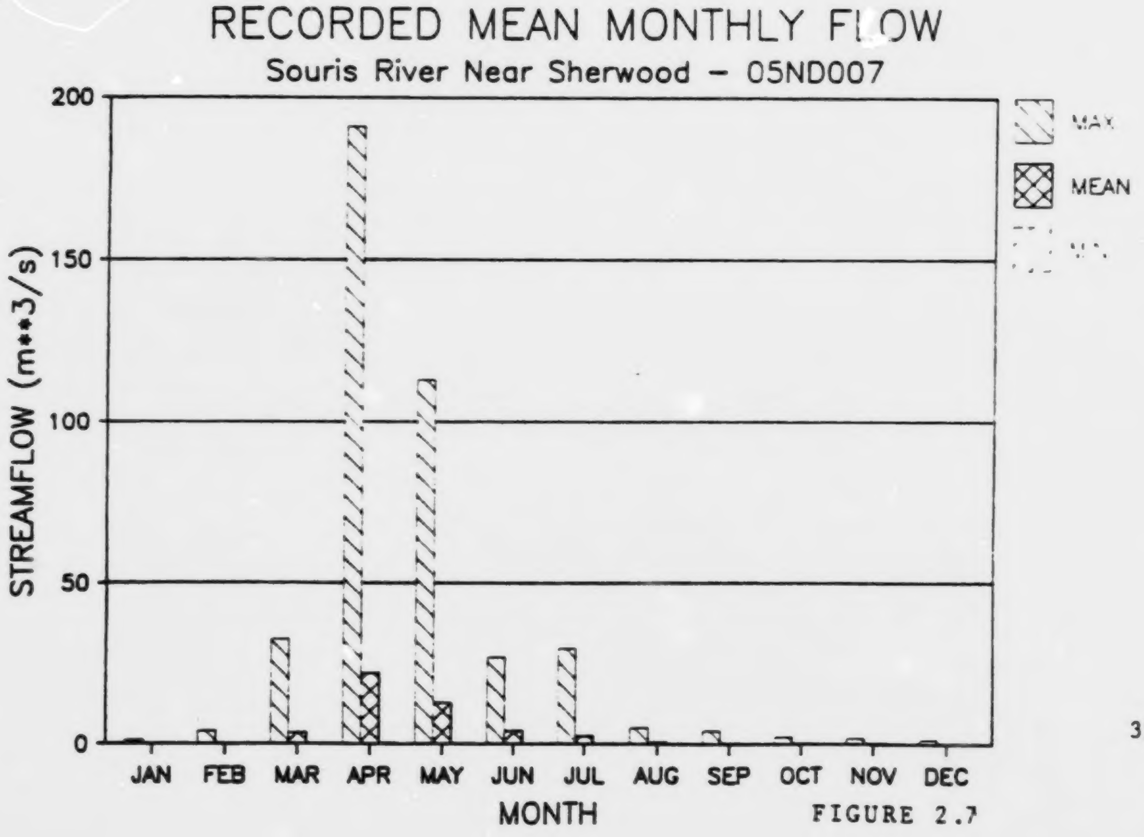

FIGURE 2.7

However, the period of record for the stations above and below Kisbey is only 14 years and for the station near Glenavon only 1 year. As the periods of record for most of these stations do not cover recent flood events which occurred during the period from 1969 to 1982, the records for Moose Mountain Creek below Moose Mountain Lake and near Oxbow, particularly the latter, are most important for this assessment. Furthermore, although the proposed Alameda dam site is approximately 13 km north of Oxbow, most of the runoff originates in the Moose Mountain area, so the flows at Oxbow have not been adjusted to compensate for any difference in catchment areas between the gauging station and the proposed dam site.

The flow records for Moose Mountain Creek near Oxbow date back to 1933. For the 49-year period 1933-1981, flows ranged from a maximum of 51.5 m^3/s to zero on many occasions, with a mean annual flow of 1.03 m^3/s. Because the mean annual flow of the Souris River at Sherwood is almost 4 m^3/s, it can be seen that the Moose Mountain Creek sub-basin contributes approximately one-quarter of the total discharge on the Souris River where it enters into North Dakota.

Moose Mountain Creek is typical of streams rising in the prairies where most of the annual flow is derived from snowmelt and early spring rain. A summary of monthly recorded streamflow for Moose Mountain Creek near Oxbow, Figure 2.8, shows that spring runoff (March to May, inclusive) accounts for some 82 percent of the mean annual runoff of 34,700 dam^3. Minimum and maximum annual recorded flow volumes were 450 dam^3 (1962) and 166,000 dam^3 (1976). Over the winter months, Moose Mountain Creek is often completely dry.

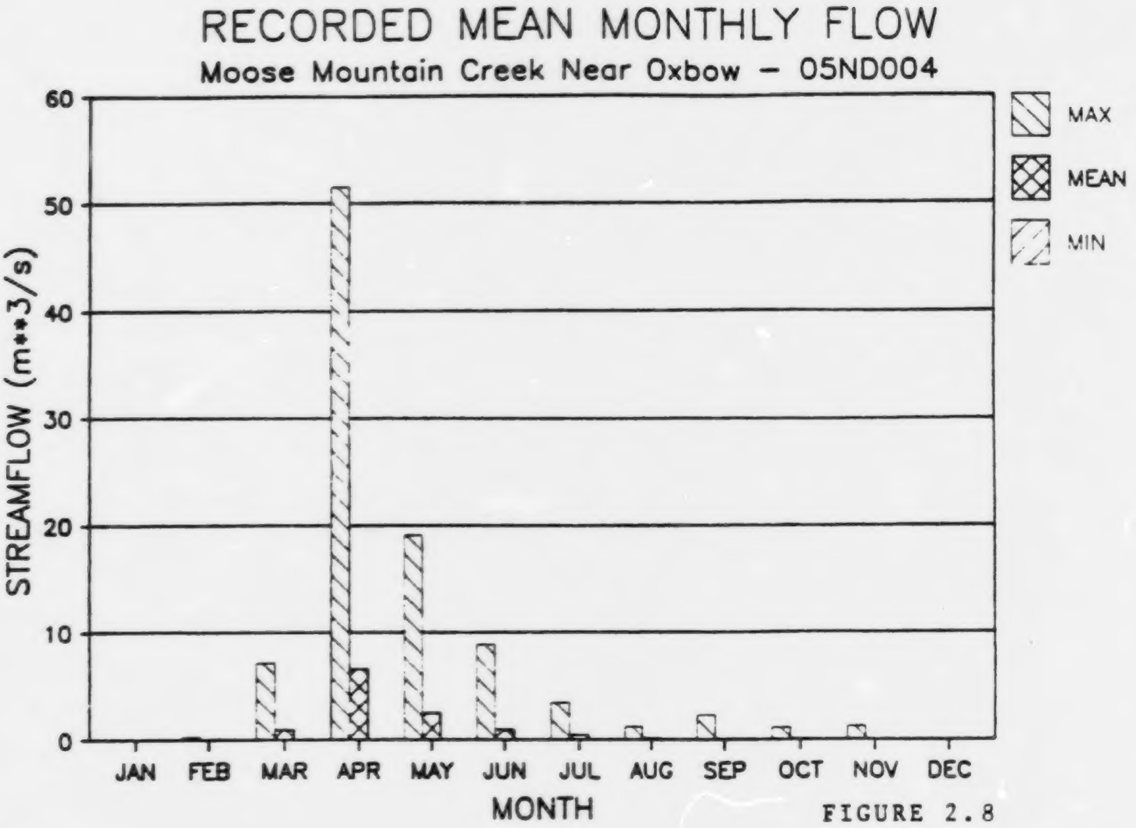

FIGURE 2.8

In addition to stream-flow data, there are some sediment data available for Station 05ND004, Moose Mountain Creek near Oxbow. The largest suspended sediment load occurs in April and, during the period 1974 to 1976, the mean load in April was 423 t/d (tonne/day). The extreme maximum daily suspended sediment load was 7,910 t/d on April 9, 1976 when the concentration was 506 mg/l.

2.3.4 Flooding

The earliest recorded flood in the Souris River was in 1882. Newspapers also reported high flows in 1904. In fact, the recorded peak flows in the Souris River at Minot, North Dakota, were 646 m^3/s in 1882 and 340 m^3/s in 1904. A comparison of the three largest floods of record is shown on Table 2.9.

TABLE 2.9

PEAK DISCHARGES OF THREE HIGHEST FLOODS
SOURIS RIVER

Year	Location		
	Melita (m^3/s)	Wawanesa (m^3/s)	Estevan (m^3/s)
1882	850	1,135	-
1904	480	570	-
1976	555	745	181.2

Source: Fennell Cochrane Lavalin (1983)

In recent years there have been a number of significant floods; peak flows are shown in Table 2.10. Hydrographs of these flood events are shown on Figures 2.9 and 2.10 for the Souris River at Roche Percee and Sherwood, respectively, and on Figure 2.11 for Moose Mountain Creek near Oxbow. The 1976 flood resulted in the highest runoff volume on record since 1912. The peak flow had an estimated return period of 150 years.

TABLE 2.10

PEAK DISCHARGE OF RECENT FLOODS
SOURIS RIVER BASIN IN SASKATCHEWAN

Location	Bank full Capacity (m^3/s)	Peak Daily Discharge (m^3/s)				
		1969	1974	1975	1976	1979
Souris River						
Weyburn (Hwy 13) (05NB028)	57	57	65	65	68	72
Near Halbrite (05NB017)	45	63	95	88	88	118
Estevan (Hwy 47)[1] (05NB007)	85	197	113	175	188	235
Roche Percee (05NB009)	85	204	118	187	206	250
Oxbow (05ND003)	227	239	201	187	408	236
Near Sherwood (05ND007)	93	311	178	191	388	239
Moose Mountain Creek						
Oxbow (05ND004)	70	113	123	76	181	88

[1] Below junction with Long Creek.

RECORDED HYDROGRAPHS

Souris River Near Roche Percee - 05NB009

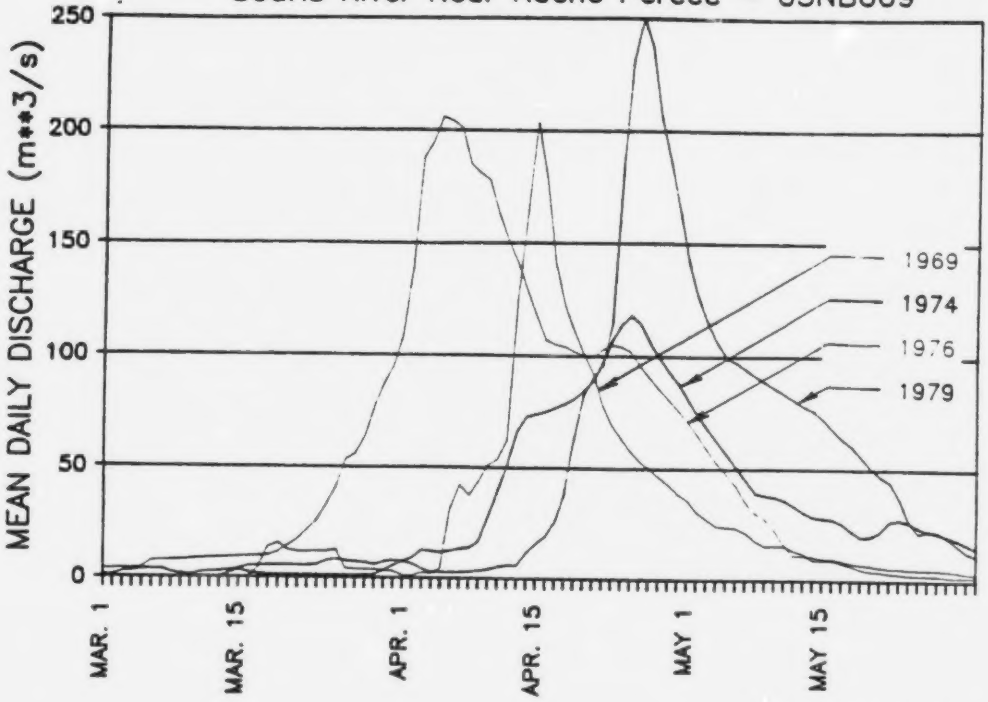

FIGURE 2.9

RECORDED HYDROGRAPHS

Souris River Near Sherwood - 05ND007

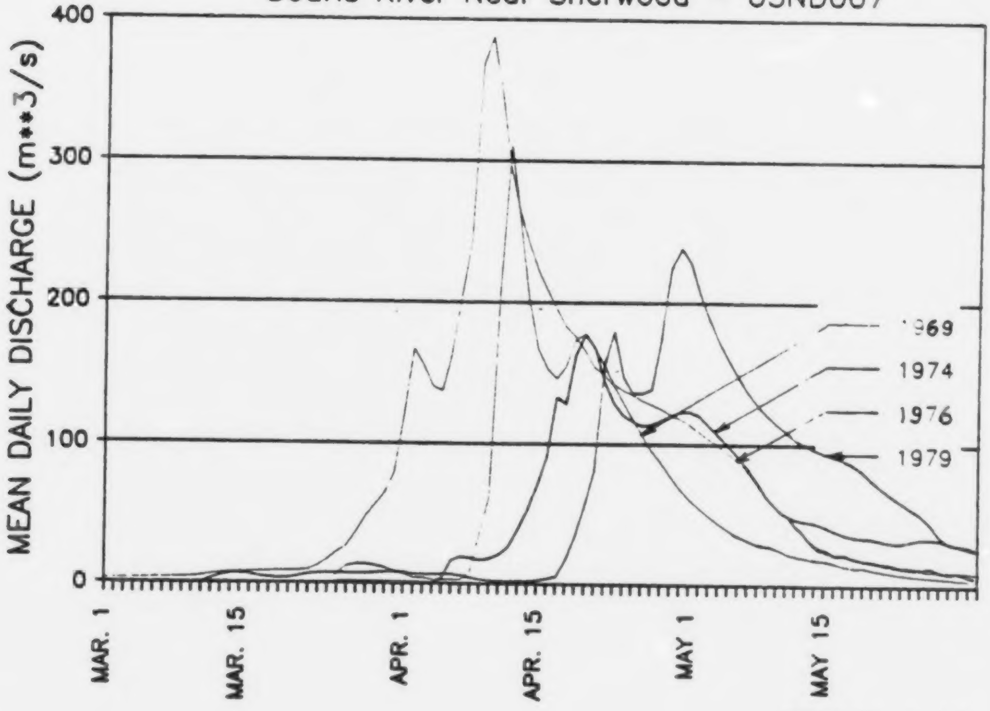

FIGURE 2.10

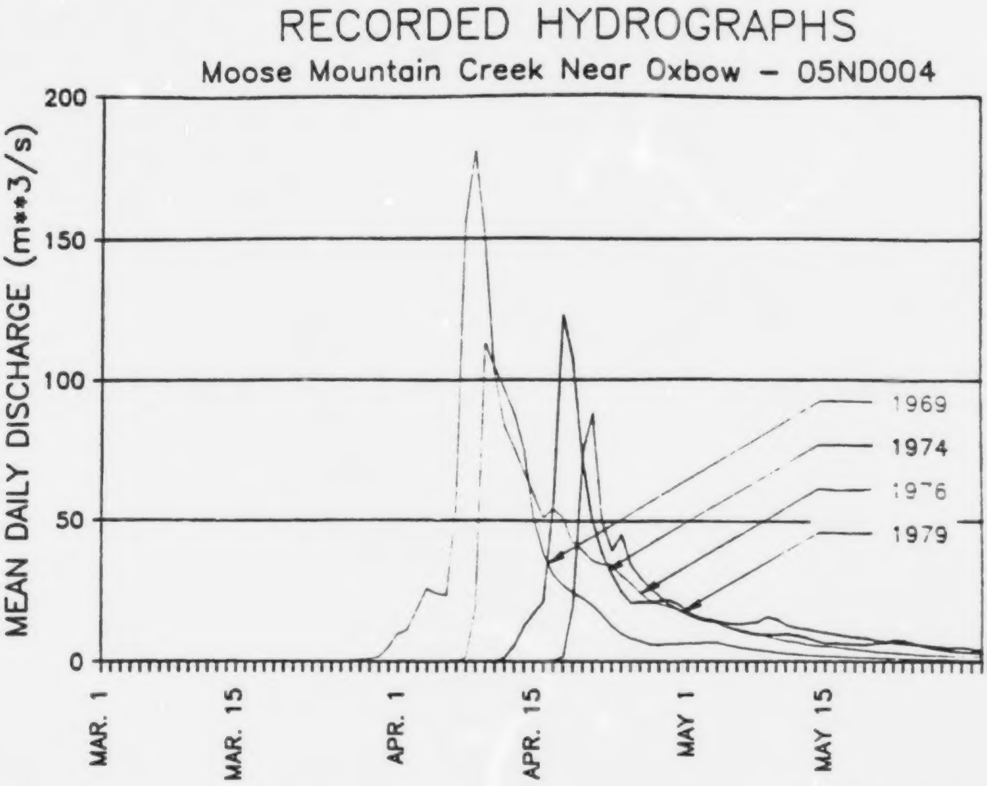

FIGURE 2.11

Hydrographs of floods in the project area typically have very steep rising limbs and somewhat flatter recession limbs. The flood peak and time to peak depend on the physiographic features of the drainage area and on climatic factors that determine the rate of melt. The parts of the drainage area that are flat and poorly drained do not contribute to the flood peak; however, they do affect the recession limbs, although this effect diminishes as the order of magnitude of the flood increases. For larger floods, the total volume of flood runoff tends to be a function of the total drainage area, the depth of the accumulated snowpack and any precipitation accompanying the snowmelt.

Theoretical flood hydrographs for the 1:50, 1:100 and 1:500 flood events have been generated for Long Creek at Estevan, the Souris River above Long Creek and Moose Mountain Creek near Oxbow as shown on Figures 2.12, 2.13 and 2.14, respectively. These theoretical hydrographs are based upon the 1976 flood hydrographs and a flood frequency analysis of peak flows.

2.3.4.1 Affects of Flooding

The flood-prone areas in the Saskatchewan portion of the Souris River valley are fairly well scattered along its length. Hence, the nature of flooding is not one of large-scale inundation. However, there have been a number of significant floods in the valley. While the larger floods have all occurred in the spring and can be attributed to a combination of snowmelt and rainfall, there has been some flooding of agricultural lands upstream of Estevan resulting from summer rains. Ice jams can also be a physical factor contributing to inundation.

Damage has been rather extensive as a result of past flooding of the Saskatchewan portion of the Souris River valley. Flooding primarily affects agricultural areas but urban centres also sustain some measure of damage. Average annual losses resulting from flooding of

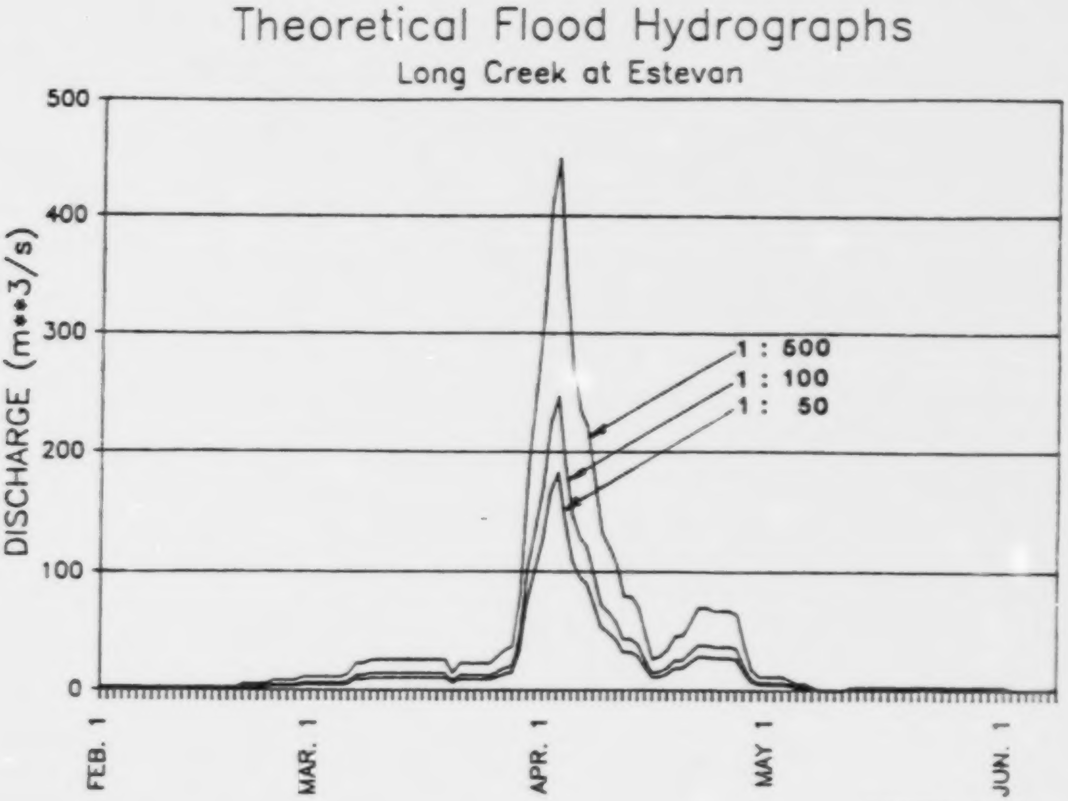

FIGURE 2.12

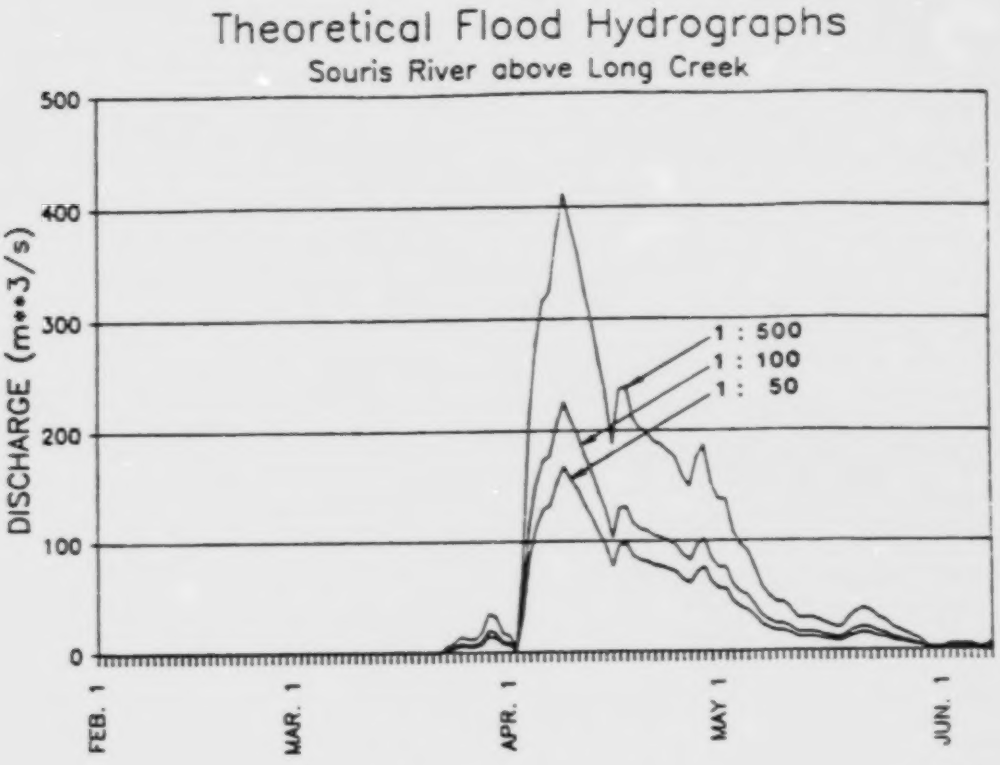

Figure 2.13

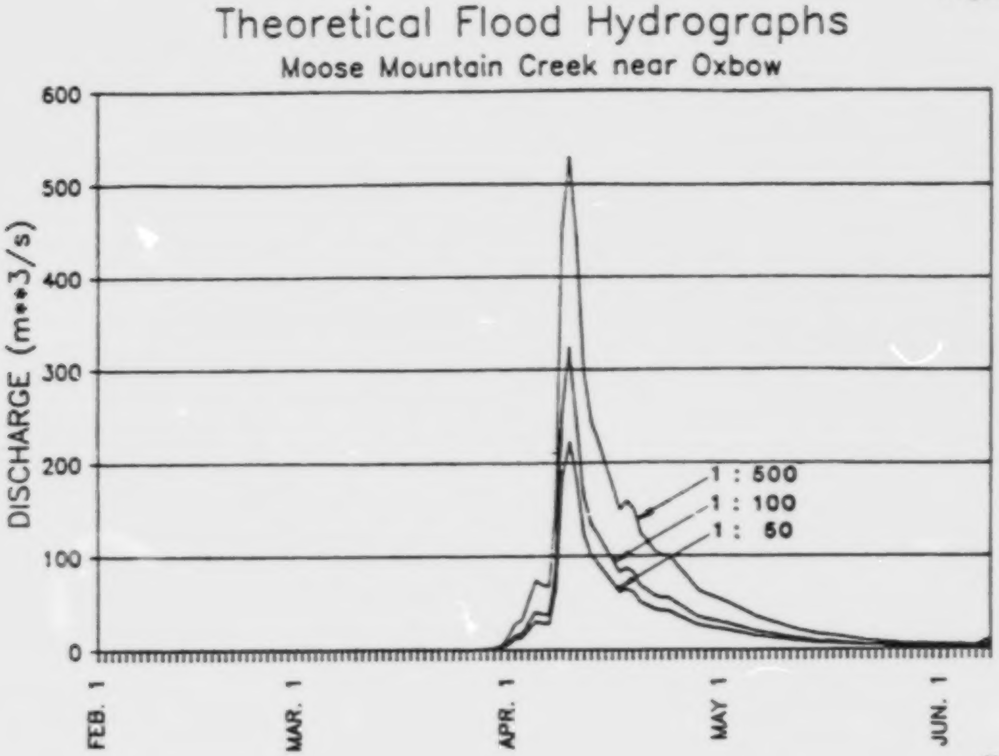

Figure 2.14

the Souris between Estevan and the North Dakota border have been estimated[4] to be in the order of $200,000 (1983 dollars). It is difficult to accurately assess the value or even the extent of other inconveniences caused by flooding. In addition, flooding frequently causes major damage downstream of the North Dakota border, particularly around Minot but this is not included in the estimated average annual damage of $200,000.

A report by PFRA (1977) defined four urban centres as potential major flood damage areas in the Souris valley in Saskatchewan. These are the City of Weyburn, Rural Municipality of Estevan No. 5, the Village of Roche Percee and the Beaver Park subdivision near Oxbow. Although potential flooding in the City of Weyburn will not be altered by the presence of Rafferty Reservoir, flooding of this area was described. Of the remaining locations the major area of potential flood damage is the Rural Municipality of Estevan No. 5. For urban areas, the flood plain was defined by the 1:500 flood and the potential annual damage assessed accordingly. For the Rural Municipality of Estevan No. 5, the land use within the flood plain is as shown in Table 2.11.

TABLE 2.11

LAND USE WITHIN FLOOD PLAIN
RURAL MUNICIPALITY OF ESTEVAN NO. 5

Type	Area (ha)
Residential	44.1
Urban Open Space	57.9
Industrial	30.3
Parks and Golf Courses	152.4
Non-Intensive Agricultural	83.9
Intensive Agricultural	102.6
Saskatchewan Power Corporation Land	148.8
Wasteland	48.2
Crown land	1.2
Municipal Services	1.4

Source: Prairie Farm Rehabilitation Administration (1977)

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[4] Rafferty Reservoir Study - Phase 2, Vol. I, Fennell, Cochrane Lavalin, January, 1985.

It should be noted that residential occupancy of the flood plain in the Rural Municipality of Estevan No. 5 has been increasing over recent years and the quality of new homes is relatively high. Under the existing levels of development, the average annual flood damage in this area has been estimated to be $10,300 (1976 dollars). The estimated value of average annual damage for each of the four urban areas affected is:

	1976 Dollars
- City of Weyburn	$28,100
- Roche Percee	4,200
- Beaver Park	270
- Rural Municipality of Estevan No. 5	10,300
Total	$42,870

In assessing rural flood damage, that is damage to agricultural land and farm dwellings, the Souris River Basin Study (PFRA, 1977) defined the flood plain by the 1:100 flood. This is mainly in the form of crop damage which depends on the time of occurrence of the flood, the depth of flooding, and particularly, the duration of inundations.

From Albert Douglas Reservoir to the international border, the average annual rural damage has been estimated to be $51,300 (1976 dollars). Of this total, $9,500 would occur in the reach between Oxbow and the border. This figure is based on information provided by farmers in the flooded areas that includes the economic loss of production from agricultural land. Losses resulting from summer flooding are normally limited to hay meadows and grazing lands near Hitchcock and to the cultivated lands in the valley downstream of Albert Douglas Reservoir.

The total damage due to flooding of the Souris River Valley from Estevan downstream to the international border has a present worth of $1.7 million. This figure[5] includes urban flood damages up to and including the 1:500 flood and rural flood damages up to and including the 1:100 flood. A more complete assessment of flood damages in updated dollars can be found in the Benefit/Cost chapter of the EIS.

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[5] Souris River Flood Study, Fennell, Cochrane, Lavalin, April, 1985.

CHAPTER 3

POST-PROJECT HYDROLOGY

3.1 INTRODUCTION

The proposed project comprising the Rafferty and Alameda Dams and associated reservoirs and the Boundary Reservoir to Rafferty Reservoir diversion is described in Chapter 1. This chapter describes in detail the approach that was used to provide an indication of how the elevation of the reservoir and flow conditions in the river reaches below the dams will be affected.

The two reservoirs will be able to store water and make it available as required. This storage will allow water from flood events to be temporarily stored and slowly released to reduce the downstream peak flows from that which would have been experienced prior to dam construction. The storage will allow water stored in relatively high flow years to be carried over into the future for use in low flow years. The diversion from Boundary Reservoir to Rafferty Reservoir will permit inflow to Boundary to be diverted to Rafferty after Boundary has filled or is assured of filling.

The results that are presented are tied directly to assumptions that have been made about how the water will be used. When reviewing the results the reader must bear in mind the type of assumptions that were attached to particular results. Consequently a variety of results is presented based on different assumptions to give the reader a perspective on the potential range of hydrologic impacts that could occur depending on how water development takes place in the future.

The chapter starts with a discussion of the operating guidelines that have been developed for the Rafferty and Alameda Reservoirs and the diversion channel. In succeeding sections it describes the water supply and flood control investigations and the associated results.

3.2 RAFFERTY AND ALAMEDA RESERVOIR OPERATING GUIDELINES

The Rafferty and Alameda Dams will be able to store water that occurs as runoff above them to develop reservoirs and release that water or otherwise make it available in a manner that meets certain objectives for water supply and flood control. The Boundary to Rafferty diversion channel will be able to divert surplus water from Boundary Reservoir to Rafferty Reservoir.

3.2.1 Flood Control

Under flood conditions, operations will be directed at trying to meet the following objectives:

(a) minimizing the flood damage potential in the Souris River in Saskatchewan;

(b) providing flood protection for floods up to and including the 1:100 for Minot, North Dakota; and,

(c) having Rafferty and Alameda Reservoirs at or below their full supply levels by September 30th each year.

Flows that cause flooding problems in the Souris River basin do not occur every year. Rather, in the majority of years, the runoff is usually confined to the banks of the Souris River in Saskatchewan. Similarly, on the Souris River in North Dakota, special operations of upstream storage will not be required in most years to prevent flooding. However, at a certain magnitude of runoff, special flood operations are required to help prevent flows from exceeding bank-full capacities. An operating plan must be followed that dictates when water should be stored or released and at what rate it should be released, based on hydrologic conditions at key control points. The specific operations might vary from year to year depending on prevailing hydrologic or physical conditions but this plan will always be directed at meeting the objectives as described above and have certain guidelines to follow.

The guidelines that will be followed to meet the above objectives are as follows:

(a) If a February 1st or subsequent spring runoff forecast shows a reasonable chance (50 percent) of a runoff volume at Sherwood hydrometric station equal to or greater than a 10 percent flood (1:10), then operations will proceed on the basis of a flood control operating plan which is agreeable to both the United States and Saskatchewan and conforms to the guidelines set out herein.

(b) In the event of a February 1st flood forecast showing a reasonable chance of occurrence of a flood volume at Sherwood equal to or greater than a 2 percent flood (1:50), pre-flood draw down of the reservoirs will be required. The releases to achieve the desired drawdown will be increased gradually in consideration of ice and channel conditions.

(c) During the period February 1st to March 15th, the combined releases from the reservoirs will be controll to prevent flows at Sherwood from exceeding 60 m^3/s (2,100 cfs).

(d) During the period March 16th to May 31st, the combined releases from the reservoirs will be controlled to attempt to limit the flow at Sherwood to a maximum of 90 m^3/s (3,200 cfs) in an attempt to prevent overbank flooding.

If forecasts indicate that either one of the reservoirs might reach the applicable maximum allowable flood level under that operation or that a flood approaching the 1 percent flood was probable, flows would be increased to a maximum of 113 m^3/s m (4,000 cfs). For larger floods (rarer than 1 percent) the channel flows would be controlled to attempt to minimize the amount of flood damage.

(e) During the period June 1st to January 31st, the combined releases from the reservoirs will be controlled to limit the flow at Sherwood at or below 11.3 m^3/s (400 cfs) unless the United States is agreeable to higher rates and excess water is available as water stored in the flood control zones of either Rafferty or Alameda Reservoirs.

(f) At all times rates of release will be dependent on channel conditions.

(g) In operating according to the above guidelines, forecasts of expected runoff and planned operation will be provided to the United States to aid their complementary operation of Lake Darling.

3.2.2 Water Supply

3.2.2.1 General

Operations to provide for water supply will be directed at the following objectives:

(a) complying with international obligations for water sharing between Saskatchewan and North Dakota;

(b) providing adequate water supply for existing authorized uses in Saskatchewan;

(c) providing a reasonable guarantee of water supply for the Shand thermal generating station; and,

(d) providing adequate water supply for new authorized uses in Saskatchewan.

The guidelines that will be followed to meet the above objectives are as follows:

(a) If a February 1st or a subsequent spring runoff forecast shows a reasonable chance (50 percent) of a runoff event less than a 10 percent flood (1:10), then operations will proceed on the basis of storing water in Saskatchewan until each of the reservoirs reaches its respective full supply level of 550.5 m on Rafferty and 574.0 m on Alameda. Once a reservoir reaches its full supply level, excess water will be released to maintain the full supply level.

(b) At its regular spring meeting, the International Souris River Board of Control will assess the runoff that has occurred to date and determine the apportionment balance. During the subsequent June 1st to September 30th period, Saskatchewan will make any releases that are necessary to meet the terms for water sharing at a rate and schedule to be determined annually by Saskatchewan but controlled to limit the rate of flow at the border according to the guidelines identified for flood control operations.

(c) All releases for apportionment will be made in consideration of United States' requirements but subject to operating constraints in Saskatchewan. The likely preference for use of storage for apportionment make-up will be first at Alameda and then at Rafferty.

(d) Water stored in Rafferty Reservoir below elevation 543.5 m will be reserved for existing use and for cooling water for the Shand thermal electric generating station.

The manner in which Rafferty and Alameda are operated to achieve the water supply objectives will vary from year to year depending on the type and level of development that has taken place to use the water, the amount of storage in the reservoirs and the type of runoff that occurs. The rate at which irrigation development takes place and hence, the rate of increase in water demand (uptake rate) will depend on economic conditions and general farmer interest.

As the irrigation development expands, the operations required to meet those increasing demands will also change. In addition, the exact location of the irrigation development, which could be downstream of Rafferty and Alameda or adjacent to the reservoirs or a mix thereof, will have a bearing on operations to meet those water demands.

3.2.2.3 International Apportionment

Certain provisions for apportionment of the Souris River water are provided in the Interim Measures recommended by the International Joint Commission. These are stated in Chapter 2.

The tentative agreement between Saskatchewan and the United States includes some suggestions for a revised sharing of the water of the Souris River.

Under certain conditions, a portion of the North Dakota share will be in the form of evaporation from Rafferty and Alameda Reservoirs. During years when these conditions occur, the minimum amount of flow actually passed to North Dakota will be 40 percent of the natural flow at Sherwood. This lesser amount is in recognition of Saskatchewan's agreement to operate both Rafferty Dam and Alameda Dam for flood control and because of evaporation losses as a result of the project. Therefore, this sharing arrangement is deemed to be in compliance with all applicable obligations.

The following rules determine the percentage of the natural flow at Sherwood which is to be passed to North Dakota.

(a) If the level of Lake Darling is below an elevation of 1,592.0 feet (485.24 metres) on October 1st in any year, Saskatchewan will pass 50 percent of the natural flow at Sherwood in that year and in succeeding years, until the level of Lake Darling is above an elevation of 1,593.0 feet (485.55 metres) on October 1st.

(b) If the natural flow at Sherwood is equal to or less than 18,500 cubic decametres (15,000 acre-feet) in any year, then Saskatchewan will pass 50 percent of that natural flow to North Dakota in that calendar year.

(c) For other years, Saskatchewan will pass at least 40 percent of the natural flow at Sherwood to North Dakota.

Lake Darling and the Canadian reservoirs will be operated (insofar as is compatible with the project's purposes and consistent with past practices) to ensure that the pool elevations, which determine conditions for sharing evaporation losses, are not artificially altered. The triggering elevation of 1,592.0 (485.24 metres) for Lake Darling is based on existing water uses in North Dakota, including refuges operated by the United States Fish and Wildlife Service. Each year, operating plans for the refuges on the Souris River will be presented to the International Souris River Joint Board of Control. Barring unforeseen circumstances, operations will follow said plans during each given year. Lake Darling will not be drawn down for the sole purpose of reaching the pool elevation of 1,592.0 (485.24 metres) on October 1st.

Late season releases will not be made by Saskatchewan Water Corporation from the Canadian reservoirs for the sole purpose of raising the pool elevation of Lake Darling above 1,593.0 (485.55 metres) on October 1st.

Regardless of the above rules, North Dakota (and the United States Fish and Wildlife Service) will assess its storage capability and need prior to release from the Canadian dams. If there will be no benefit in North Dakota from the release, the water may be retained for use in Saskatchewan. To the extent possible and in consideration of potential channel losses, releases from the Canadian dams under the above rules will be scheduled to coincide with periods of beneficial use in North Dakota. All releases will be within the specified target flows at control points and the timing of said releases will be co-ordinated with the United States Fish and Wildlife Service.

3.3 WATER SUPPLY STUDIES

3.3.1 General

The potential water supply impact of the proposed Rafferty and Alameda Reservoirs was investigated with the use of a computerized water balance model. The results presented in this chapter were determined based on the application of the Alberta Environment Water Resource Management Model (WRMM). This model was developed by the Government of Alberta especially for analysis of complex river basin water supply problems. Sask Water acquired this model for this investigation since, of all available water balance models, it was considered the most sophisticated in terms of its ability to deal with complex multi-reservoir simulations.

The characteristics of this model, the data and assumptions used in the analysis and the results are subsequently discussed.

3.3.2 Water Resource Management Model (WRMM)

The model provides the ability to assess planning alternatives in the context of present or projected water requirements and the natural water supply. The WRMM simulates water allocation within a water resource system over a discrete, but continuous, set of time periods. The calculations are steady state balances (i.e. no account is taken of the "time of travel" of water).

The model is capable of representing any water resource system which incorporates the following physical processes:

(a) natural runoff;
(b) precipitation and evaporation from reservoirs;
(c) storage and release of water by reservoirs;
(d) diversion channels;
(e) irrigation consumption and return flows;
(f) hydropower production;
(g) major consumptive demands with return flows, e.g., large city or industry; and,
(h) minor consumptive demands without return flows, e.g. rural, small municipal and stock watering.

Included within natural runoff is all water contributed from the catchments to the river channels under natural conditions. Thus, natural runoff includes the effects of any naturally occurring lakes, such as storage and evaporation, but excludes the effects of any man-made reservoirs, diversions and withdrawals from the rivers.

The response of a river system to the natural river flow and climatic conditions of an historic period or any derived stream flow and climatic conditions can be simulated. The model is also capable of simulating differing channel flow constraints and a wide range of operating policies used to allocate water within the basin. These policies specify priorities for the various water demands and preferred reservoir storage and channel conditions. Channel conditions include instream demands, such as flow requirements for effluent dilution and the preservation of fish and wildlife, and downstream demands such as for meeting the requirements for apportionment with a downstream jurisdiction.

The WRMM models the range of characteristics in a river system by the use of a standard set of components, each representing a specific physical process. These components are linked together by a master control section to represent the physical river system. The components which are available for use are outlined in Table 3.1.

To simulate a river system the modelled system is translated into a flow network composed of nodes interconnected by flow links to represent water movement. Each node or flow link in the network represents one of the model components. Nodes are used to represent points of inflow, storage or diversion; reservoirs and river and canal junctions act as nodes. Flow links define surface water movement from one location to another, e.g. river reaches, diversion canals and return flow channels.

TABLE 3.1

WATER RESOURCE MANAGEMENT MODEL COMPONENTS

No.	Component Name	Modelled Processes
1.	Reservoir (represented as a node)	- storage - releases (excluding hydropower) - net evaporation
2.	Hydropower (represented as a flow link)	- power flows - energy generation
3.	Natural Channel (represented as a flow link)	- channel flow
4.	Apportionment Channel (represented as a flow link)	- channel flow which is governed by an apportionment agreement
5.	Diversion Channel (represented as a flow link)	- gravity or pumped flow in a diversion channel
6.	Irrigation (represented as a node)	- consumptive use - return flow
7.	Junction* (represented as a node)	- joining of flow from two or more components; also splitting of flow to two or more components
8.	Major Withdrawal (occurs at a node)	- consumptive use - return flow
9.	Minor Withdrawal (occurs at a node)	- consumptive use
10.	Inflow (occurs at a node)	- represents runoff between a node and the node directly above it

* Natural runoff is simulated as Inflow at Reservoirs and Junctions.

The WRMM produces the following output:

(a) channel flow in cubic metres per second;
(b) reservoir elevation in metres;
(c) power production by hydropower plants in megawatts;
(d) consumption of water by major and minor withdrawals in cubic metres per second;
(e) consumption of water in the irrigation components expressed as an application of water over unit area in millimetres; and,
(f) return flows in cubic metres per second.

A data value is produced for each component, with the exception of junctions, in the modelled system for each time interval simulated. Junctions which conserve flow are necessary to define the topology of the river system by connecting two or more channels.

The simulation period for which the model is run is based on a number of simulation cycles. Each cycle contains a continuous number of time intervals for which data are provided and results produced. Each time interval is specified as a number of days and can thus represent daily, weekly or monthly values. The most common use of the WRMM to date has specified monthly intervals and annual cycles for basin planning.

The WRMM requires four basic sets of data to simulate a river system. These are:
(a) definition of the physical system;
(b) assignment of priorities for water use which define the operating policy;
(c) water supply data; and,
(d) water demand data.

The physical system is defined in terms of the components listed in Table 3.1. Each discrete component represents one specific physical process in the modelled river basin. How the components are connected must also be specified.

The system operating policy is represented by defining, for each component, an ideal state and a number of zones representing deviations above and below the ideal state. During the simulation, the model satisfies all ideal requirements if there is enough water available. If not, it satisfies the requirements in order of priorities assigned by the user. The priorities are specified by the use of penalty value allocations to the zones that represent deviation from the ideal condition. During a model simulation, deviations first occur in those zones having low penalty values and then proceed into zones having higher values.

The water supply data define initial storage, inflows and losses, i.e.:
(a) initial reservoir storages;
(b) natural flows; and,
(c) reservoir evaporation, net of precipitation.

The water demand data comprise:
(a) municipal and industrial consumption;
(b) irrigation requirements; and,
(c) hydropower requirements.

3.3.3 Application of Water Resource Management Model

3.3.3.1 Basin Representation

To model the Souris River basin, requires that the basin be divided into a flow network composed of nodes interconnected by flow links to represent water movement. Figure 3.1 shows a schematic of the basin model. The schematic shows where runoff inflows were added to the system and where water demands were extracted. All the major existing reservoirs (Weyburn, Roughbark, Boundary and Moose Mountain) have been included along with the proposed Rafferty and Alameda Reservoirs. The system modelled in this way is directed at providing an accurate accounting of supply and use at three primary control points: Rafferty Reservoir, Alameda Reservoir and the International Border.

3.3.3.2 Natural Flow Data

At a hydrometric station where stream flow rates and volumes are recorded, the measured flow can be considered to be a natural flow if there were no man made works upstream that temporarily stored or diverted any of the runoff. If works exist, then the effect of those works on the runoff must be accounted for to reconstruct natural flows with recorded data. The changes to the natural flow can be accounted for with works that divert water for consumption; reservoir works that store water and change downstream flow patterns and also induce extra evaporation losses that would not otherwise have occurred under natural conditions; and works that drain water to the place of flow measurement. These effects or adjustments can be estimated for historic conditions and combined with the recorded flow records to reproduce estimates of natural flow.

These adjustments were of the following types.

(a) Municipal and industrial use;
(b) Minor uses for irrigation, domestic and stock watering;
(c) Natural evaporation on existing reservoirs;
(d) Forced evaporation at Boundary Reservoir from induced heating of the reservoir water due to use of water for thermal electric plant cooling;
(e) storage changes on existing major reservoirs; and,
(f) flows created by drainage works that contribute runoff to the stream that would not contribute under natural conditions.

Monthly mean natural flows were developed at ten sites in the Souris River basin in Saskatchewan for the period 1912-1981. Further details on the methodology can be found in Reference 5.

The natural flow study points that were used in the modelling are shown on Figure 3.1. Modelling with natural flow estimates at these locations ensured that an accurate representation could be made for hydrologic conditions at Rafferty and Alameda Reservoir sites and at the International Border.

The natural flow estimates used in the modelling can be found listed in Appendix A.

3.3.3.3 Evaporation and Precipitation Data

The amount of water lost through direct evaporation and gained through direct precipitation was simulated for each reservoir that was included in the model. For each reservoir, the monthly precipitation and evaporation values were determined using historical meteorological observations at Estevan and Broadview. The methodology used to develop estimates followed that used in the Saskatchewan Nelson Basin Board Study (Reference 1). The observations at these two sites had to be used to develop estimates for the full period of record from 1912 to 1981. More details on how the data were developed for each site can be found in Reference 5.

3.3.3.4 Rafferty and Alameda Storage Characteristics

The reservoir characteristics in terms of the relationship between elevation and storage volume, and elevation and reservoir surface area, can be found on Figure 3.2 and Figure 3.3. These characteristics define the reservoirs for modelling purposes so that accurate estimates of net evaporation losses can be determined and an accurate representation of changes to surface water elevations can be determined as a result of changes in reservoir storage.

3.3.3.5 Operating Rules

As specified in the operating guidelines, both Rafferty and Alameda Reservoirs would be allowed to increase their water levels during spring runoff, if necessary, to a maximum flood level and then drawn down as soon as possible after spring runoff to their full supply levels. These respective elevations are shown in Table 3.2.

TABLE 3.2

RESERVOIR CHARACTERISTICS

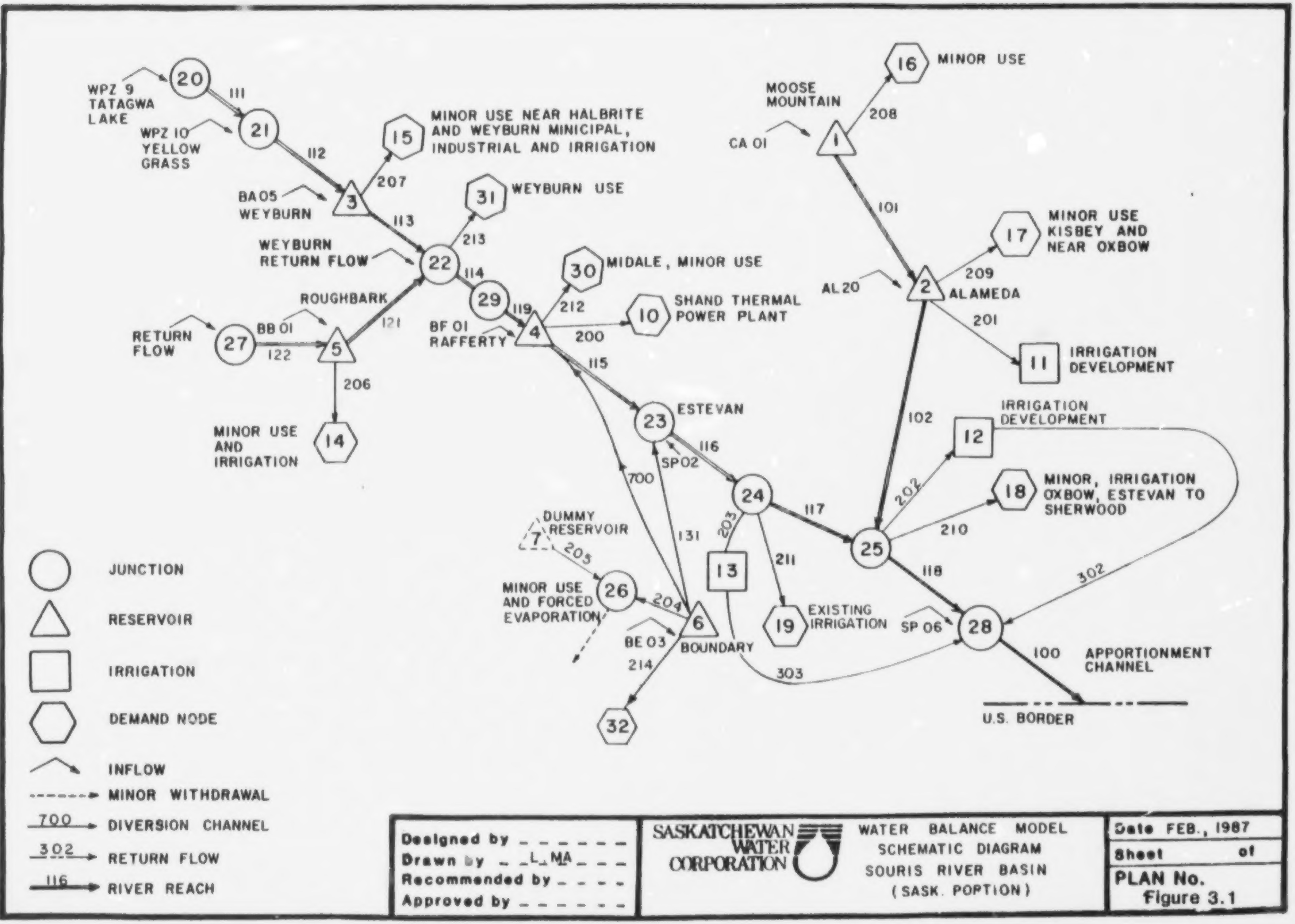
Condition	Rafferty Reservoir Site C Elevation (m)	Rafferty Reservoir Site C Storage (dam^3)	Rafferty Reservoir Site C Area (ha)	Alameda Reservoir Elevation (m)	Alameda Reservoir Storage (dam^3)	Alameda Reservoir Area (ha)
Maximum Flood Control Storage1)	554.0	632,400	6,217	579.0	183,000	2,210
Maximum Water Supply Storage2)	550.5	439,500	4,877	574.0	96,600	1,340
Minimum Operating Storage3)	537.5	9,660	1,176	564.0	18,900	380

1) This criterion represents the maximum quantity of water that can be safely stored during flood conditions and generates the highest elevation to which water will be stored in the reservoir.

2) This condition is targeted for as soon as possible after a flood.

Water will only be stored above this elevation to reduce the potential for flood damage downstream and will be released as soon as possible in a controlled manner that does not contribute to flood damage downstream.

3) This condition is represented by the minimum elevation at which releases can be made from the reservoir.



Designed by - - - - - -
Drawn by - - L. MA - - -
Recommended by - - - -
Approved by - - - - - -

SASKATCHEWAN WATER CORPORATION

WATER BALANCE MODEL
SCHEMATIC DIAGRAM
SOURIS RIVER BASIN
(SASK. POPTION)

Date FEB., 1987
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PLAN No.
Figure 3.1

RAFFERTY RESERVOIR

Area – Capacity Curves

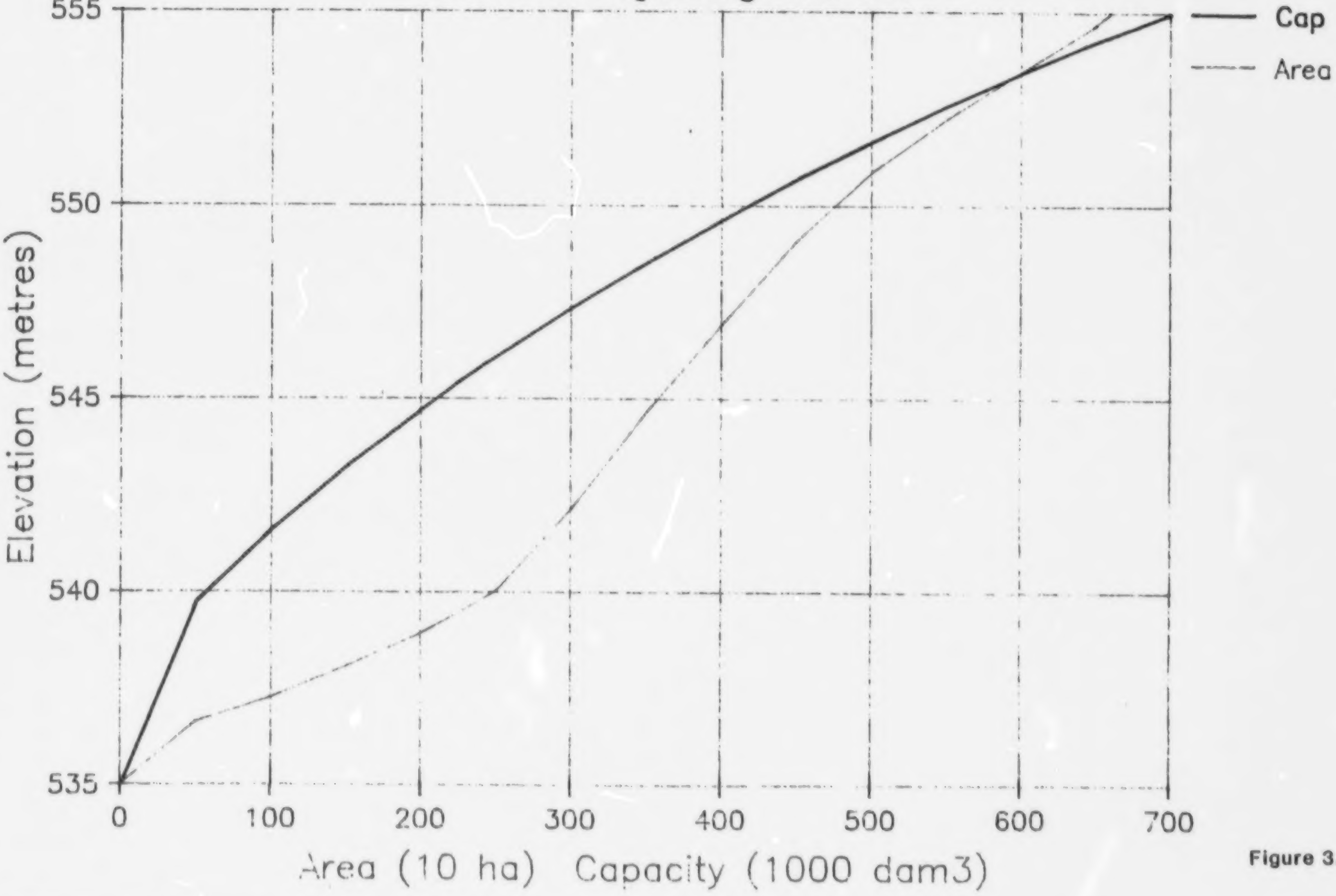


Figure 3.2

SOURIS RIVER BASIN

Alameda Reservoir Area – Capacity Curves

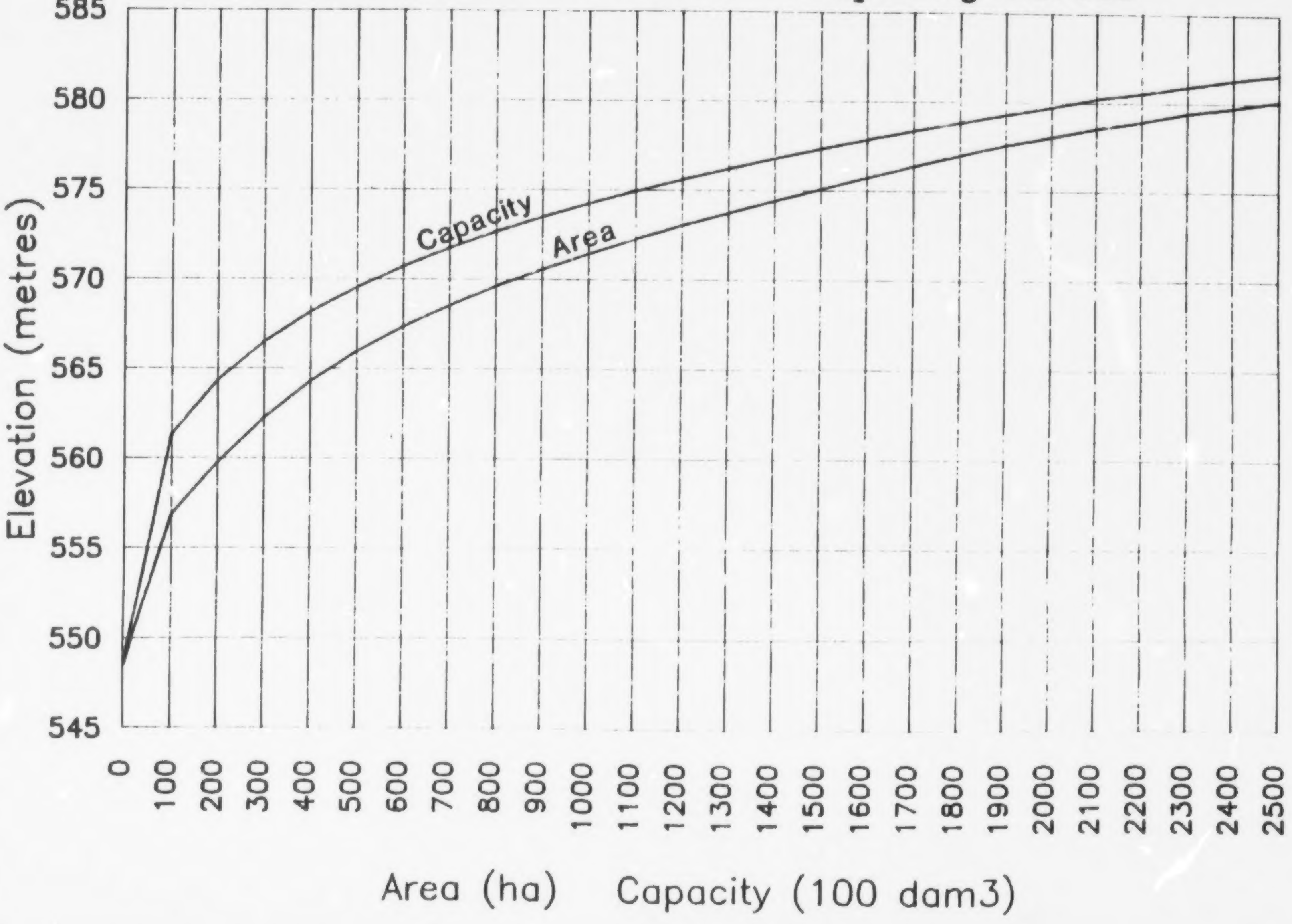


Figure 3.3

The water stored in these reservoirs was allocated according to the following priorities from highest to lowest:

(a) The requirements for International Apportionment, first from Alameda to the extent that water is available and then from Rafferty Reservoir.
(b) The cooling water requirements for the Shand thermal electric generating station.
(c) Authorized uses in Saskatchewan existing prior to construction of the dams.
(d) New authorized uses in Saskatchewan.

In the course of the water supply investigations, it was determined that the amount of water stored below elevation 543.5 m in Rafferty would be required to guarantee cooling water supply for the Shand thermal electric generating station during a period of extreme drought such as the 1930's. Consequently, on Rafferty Reservoir, new uses would be allowed to only use water stored above elevation 543.5 m. It would not be necessary to put a similar restriction on Alameda Reservoir.

In the interest of maintaining the viability of upstream uses, the other reservoirs were maintained at their respective full supply levels to the extent that the existing allocations from those reservoirs would permit. The storage in these reservoirs was not drawn on to augment supply in either Rafferty or Alameda or to meet the demands of new uses that were simulated (i.e. expanded irrigation).

3.3.3.6 Simulation Period

Monthly natural flows were reconstructed for the period 1912 to 1981. Because of the unavailability of recorded data prior to 1912, it was not possible to develop natural flows prior to that date. The effort to develop natural flows was initiated in 1982; hence, the natural flow record was reconstructed to 1981, the latest full year of record that was available at that time.

The entire period 1912 to 1981 was simulated on a monthly basis with the water balance model and that period is considered adequate to test the project against the range of hydrologic conditions from flood to drought.

3.3.3.7 Initial Conditions

The objective of the computer simulations is to show the long-term hydrologic response of the proposed projects. It is recognized that it will be sometime in the future before the full potential use that has been simulated will be in place. Experience has shown that it will take time to get new irrigation development underway, perhaps up to ten years before the full development potential will be realized (Reference 7). Similarly it will take time to fill the reservoirs. Because of the unknowns associated with these start-up conditions and in the interest of portraying the long-term conditions it was assumed for the computer simulations that Rafferty and Alameda Reservoirs would start nearly full in 1912 with respective initial elevations of 549.5 m and 572.0 m. The issue of "fill time" is addressed in a separate analysis under subsection 3.4.

3.3.3.8 Water Use

Work done previously by Fennell, Cochrane, Lavalin (Reference 5) showed the potential for increased demand for water in the entire Souris River basin. These future uses also took into account the existing use described in Chapter 2. However, to model the hydrologic response of Rafferty and Alameda Reservoirs it was necessary to identify only those uses that would impact directly on the reservoir. The only existing uses that were accounted for were those that:

- would impact directly on the supply into the reservoirs and were taken into account in the development of the natural flows; or,

- could be supplied with releases from the reservoir and historically have taken their supply directly from the Souris River.

Most of the estimates of water use that were included in the simulations were developed by Fennell, Cochrane, Lavalin (Reference 5). These are described as foreseeable future uses representing the expected level of use by 1991, based on forecasts made in 1981. The water uses that were used in the modelling are shown in Tables 3.3 and 3.4. The values in Table 3.4 represent uses that were licenced between 1981 and 1986. Tables 3.5 and 3.6 show how the uses were distributed to the various model nodes identified on Figure 3.1. These uses are discussed subsequently.

Municipal Use

Municipal consumption from Estevan, Weyburn, Radville, Midale and Oxbow was considered to impact directly on the proposed reservoirs and associated Souris River flows. The foreseeable future municipal use for Weyburn and Estevan was respectively 2,200 and 2,000 dam^3 per year. The 1986 use for Weyburn and Estevan was respectively 1,751 dam^3 and 1,373 dam^3 which are both significantly less than the modelled use.

Municipal return flows were simulated for Weyburn. Prior to 1984 the city of Weyburn discharged from its sewage lagoon continuously, but since that time the city has discharged its lagoons semi-annually which is how the discharge was modelled. The City of Estevan sewage discharge was modelled as being used by the Shand thermal electric generating station as a source of cooling water (see Shand section). The Radville lagoons were assumed to be drained in April.

Existing Thermal Power Cooling

Boundary Reservoir is used as a source for cooling water for the Boundary thermal electric generating units. This use causes water to be evaporated at a rate in excess of that which would be experienced without circulation of the water for cooling purposes. This use is generally referred to as forced evaporation. The amounts of monthly forced evaporation that were simulated are shown in Table 3.3 as use #11. Currently, the Estevan Generating Station uses water from the Souris River for cooling purposes. However, when the Shand station commences operation, the Estevan Generating Station will not be operated and therefore its use was not simulated.

Table 3.3

FORESEEABLE FUTURE MAJOR AND MINOR WATER DEMAND ARRAYS (m^3/s)
SASKATCHEWAN PORTION - SOURIS RIVER**

	USE NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	CU.DAMS^1
1	Tatagwa Lake Drain	- - - - - - - - - - - - - - - MATRIX OF MONTHLY VALUES 1912-1981 - - - - - - - - - - - - - - -												Varies^3
2	Yellow Grass Ditch	- - - - - - - - - - - - - - - MATRIX OF MONTHLY VALUES 1912-1981 - - - - - - - - - - - - - - -												Varies^3
3	Minor Use Near Halbrite	0	0	0	.302	0	.001	.002	.001	0	0	0	0	786
4	Weyburn Municipal	.059	.059	.059	.063	.080	.088	.104	.075	.071	.063	.055	.059	2200
5	Weyburn Industrial*	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Weyburn Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Minor Roughbark	0	0	0	+.125	-.010	-.032	-.035	-.015	-.006	0	0	0	71
8	Roughbark Irrigation Net	0	0	0	0	.007	.025	.027	.013	.004	0	0	0	200
9	Above Boundary - (Minor Uses and Radville)	.005	.005	.005	.762	.005	.026	.028	.025	.005	.005	.005	.005	2316
10	Boundary - Estevan Munic.	.053	.053	.053	.057	.072	.080	.095	.068	.065	.057	.053	.053	2000
11	Boundary - Forced Evap.	.252	.213	.228	.208	.198	.149	.166	.171	.183	.228	.238	.238	6510
12	Wey. Return and Minor	0	0	0	+.187	-.011	+.050	+.047	+.069	-.006	-.217	0	0	103
13	Souris Channel Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0
13a	Dead Lake Irr., Midale, Minor	.002	.002	.002	.003	.013	.038	.042	.021	.008	.002	.002	.002	360
14	Estevan Ret'n and Minor Near Estevan	-.002	-.002	-.002	-.068	-.015	-.032	-.035	-.007	-.006	-.268	-.002	-.002	-1070
15	Thermal and Irrig. Estevan	.002	.002	.002	.002	.007	.023	.024	.013	.005	.002	.002	.002	226
16	Souris Irrig. Near Estevan	0	0	0	0	.008	.030	.032	.015	.001	0	0	0	226
17	Estevan to Sherwood (Minor, Irrig. and Returns)	0	0	0	+.411	-.007	-.023	-.026	-.012	-.004	0	0	0	891
18	Irrig. Near Oxbow	0	0	0	0	.005	.016	.018	.008	.003	0	0	0	131
19	Minor Below Moose Mt. Res.	0	0	0	.152	0	0	0	0	0	0	0	0	394
20	Moose Mt. Irrig.	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Minor Use Kisbey and Near Oxbow	0	0	0	.184	0	0	0	0	0	0	0	0	477

[1] Annual Total Is Approximate

[2] Positive Values In Table (+) Are Demands From The Souris River
Negative Values In Table (-) Represent Returns To The River

[3] Refer To Appendix A

* 300 dam^3/yr Included With Municipal.

** Source: Table 6.2.3, FCL Report, Ref. No. 5.

Table 3.4

LICENCED ALLOCATIONS 1981-1986*
SOURIS RIVER BASIN
(m^3/s)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Below Rafferty	0	0	0	0	.003	.012	.013	.0065	.0016	0	0	0
Above Boundary	.002	.002	.002	.002	.0068	.019	.021	.012	.0045	.002	.002	.002
Above Rafferty	.005	.005	.005	.006	.007	.0108	.0113	.011	.0066	.005	.005	.005
Above Alameda	0	0	0	0.36	.0065	.024	.026	.013	.0035	0	0	0

* Source: Saskatchewan Water Corporation Water Licence Records.

Table 3.5

MODELLED WATER USE
SOURIS RIVER BASIN
(m^3/s)

MODEL NODE*	DESCRIPTION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
15	Minor Use Near Halbrite and Weyburn - Municipal, Industrial and Irrigation	.059	.059	.059	.365	.080	.089	.106	.076	.071	.063	.055	.059
31	Weyburn Minor Use	0.0	0.0	0.0	.187	0.0	.05	.047	.069	0.0	0.0	0.0	0.0
14	Roughbark Minor Use and Irrigation	0.0	0.0	0.0	.125	.007	.025	.027	.013	.004	0.0	0.0	0.0
30	Midale Minor	.007	.007	.007	.008	.009	.021	.023	.014	.008	.007	.007	.007
10	Shand Thermal Power Plant	.065	.072	.109	.145	.240	.217	.224	.217	.187	.129	.077	.077
19	Estevan Local Irrigation	.002	.002	.002	.002	.01	.035	.037	.018	.007	.002	.002	.002
26	Boundary, Municipal and Forced Evaporation	.305	.271	.281	.265	.270	.229	.261	.239	.248	.285	.291	.285
18	Minor and Irrigation Near Oxbow and Estevan to Sherwood	0.0	0.0	0.0	.411	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	Minor Below Moose	0.0	0.0	0.0	.152	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	Minor Use at Kisbey and Near Oxbow	0.0	0.0	0.0	0.544	.0065	.024	.026	.013	.0035	0.0	0.0	0.0
32	Boundary Minor	.007	.007	.007	.764	.0118	.045	.049	.037	.0095	.007	.007	.007

* Refer to Basin Schematic.

Table 3.6

RETURN FLOWS FROM FUTURE WATER USES*
SOURIS RIVER BASIN
(m^3/s)

MODEL NODE	DESCRIPTION	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
27	Roughbark Return	0.0	0.0	0.0	0.0	.01	.032	.035	.015	.006	0.0	0.0	0.0
22	Weyburn Return**	0.0	0.0	0.0	.325	.011	0.0	0.0	0.0	.006	.217	0.0	0.0
23	Estevan Return**	.002	.002	.002	.002	.015	.032	.035	.035	.006	.002	.002	.002
25	Estevan to Sherwood Return	0.0	0.0	0.0	0.0	.002	.007	.008	.004	0.0	0.0	0.0	0.0

* Source, Table 6.2.3, FCL Report, Ref. No. 5.
** Updated values.

Minor Use

A number of existing minor uses for domestic and livestock purposes were increased according to the growth forecasts developed by Fennell, Cochrane, Lavalin (Reference 5) to correspond to the expected 1991 level of use. These uses are identified as "minor uses" for a number of locations in Table 3.3.

Existing Irrigation Use

Water use for irrigation was divided into existing and new potential use. The existing use for irrigation was based on the quantity of use licenced up to 1986. It was simulated separately from the new irrigation since it was considered to have priority for access to water over new irrigation development. Existing irrigation use was simulated from the following sources: Long Creek above Boundary Reservoir, Roughbark Creek, Souris River above Weyburn, Souris River from Rafferty to the border, Moose Mountain Creek above Moose Mountain Reservoir and Moose Mountain Creek near Oxbow. These uses in terms of both diversions and return flows are shown in Table 3.3. In some cases the irrigation use, minor use and irrigation return flow are lumped for convenience of modelling and a net value is shown in the Table.

The existing irrigation in the Weyburn to Rafferty river reach (Dead Lake Water Users) will not be possible in the future since the land currently irrigated will be permanently flooded. Therefore, that use was not modelled.

Shand Thermal Electric Plant Use

Water will be supplied from Rafferty by pipeline to the Shand thermal electric power plant for cooling purposes.

The total annual water requirement of the Shand generating station will be approximately 6,400 dam^3. Most of this will be supplied from Rafferty

Reservoir. However, a portion of the requirement will be supplied from the Estevan sewage lagoons.

Based on a foreseeable future annual diversion for Estevan municipal purposes of 2,000 dam^3, the annual lagoon discharge was assumed to be 1,500 dam^3*. In addition, approximately 260 dam^3 will be available for cooling purposes from coal mine dewatering.

The monthly diversion requirements from Rafferty are shown on Figure 3.4. This is a typical distribution assumed for purposes of modelling. The actual quantity to be licenced for Rafferty at the time of commissioning of the second unit at Shand will depend on the amount of sewage effluent available which could be more or less than the best estimate of 1,500 dam^3. The annual diversion amount is approximately 4,640 dam^3 (6400-1500-260).

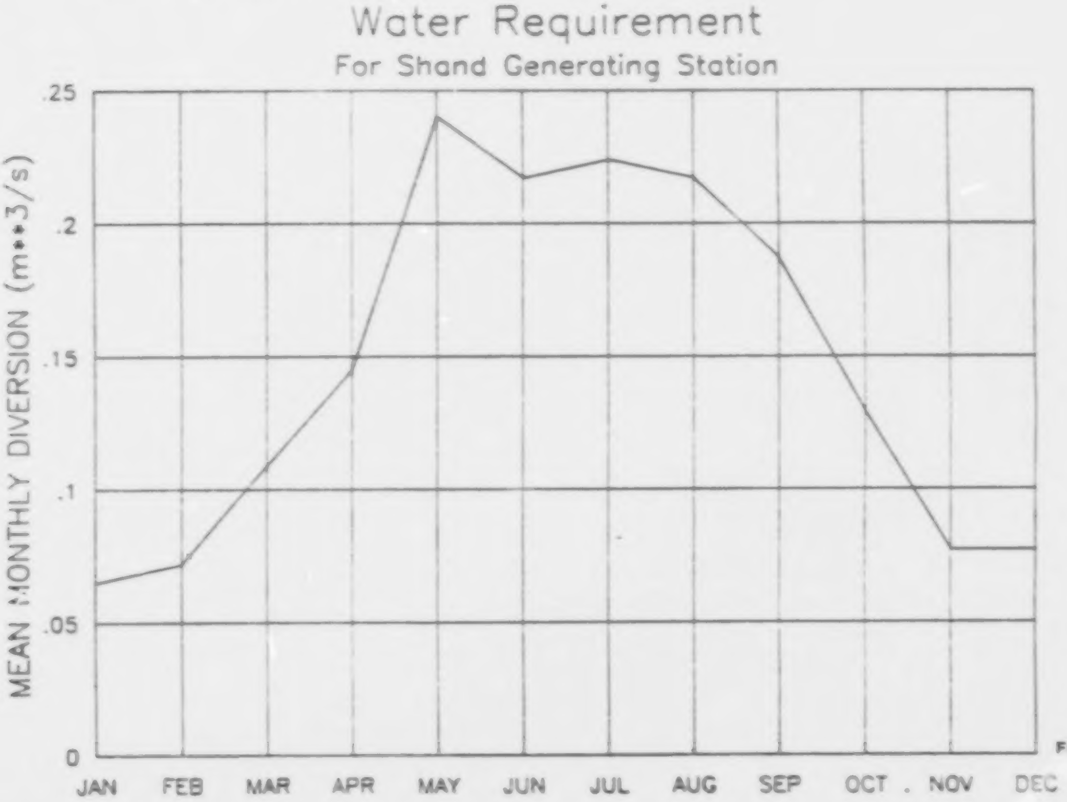


Figure 3.4

* Personal communication M.R.2 McDonald and Associates

New Irrigation Use

Water Resource Consultants (Reference 7) determined that up to 7,200 ha of land could be economically irrigated using Rafferty and Alameda Reservoirs as the supply sources. They determined that up to 3,200 ha could be supplied from Rafferty Reservoir and 4,000 ha from Alameda Reservoir. They also proved out the suitability of soils to accommodate the potential development. The irrigation could take place either as upland irrigation adjacent to the reservoirs or as a combination of upland and lowland irrigation. Lowland irrigation is considered to be irrigation development in the Souris River valley between Rafferty Reservoir and the International Border. The study determined that over 3,200 ha of land are suitable for irrigation in the river valley and that lowland irrigation was the most economic to develop.

Based on that assessment and follow-up analyses, it was concluded that although a maximum of 7,200 ha of land could be economically developed with the two reservoirs, such a large development would produce reservoir elevation fluctuations and extremes that would likely conflict with recreation development on the reservoirs. Consequently, it was considered that a more compatible scenario for maximum irrigation development would be in the order of 4,800 ha. Water allocation for that amount of area will ensure a more economical irrigation development with a lessor frequency and magnitude of shortages than for a development of 7,200 ha.

Because lowland irrigation is the most economic and has been practiced to date along the Souris River, it was assumed that most of the irrigation development would be taken up with the development of the 3,200 ha of valley land classified as suitable for irrigation in the lowland. Approximately 2,000 ha could be supplied with releases from Rafferty Reservoir and 1,200 ha could be supplied out of Alameda Reservoir. The remainder of the development was assumed to take place as upland irrigation (1,600 ha) adjacent to Alameda Reservoir.

DISTRIBUTION OF IRRIGATION WATER USE

Monthly Percentage

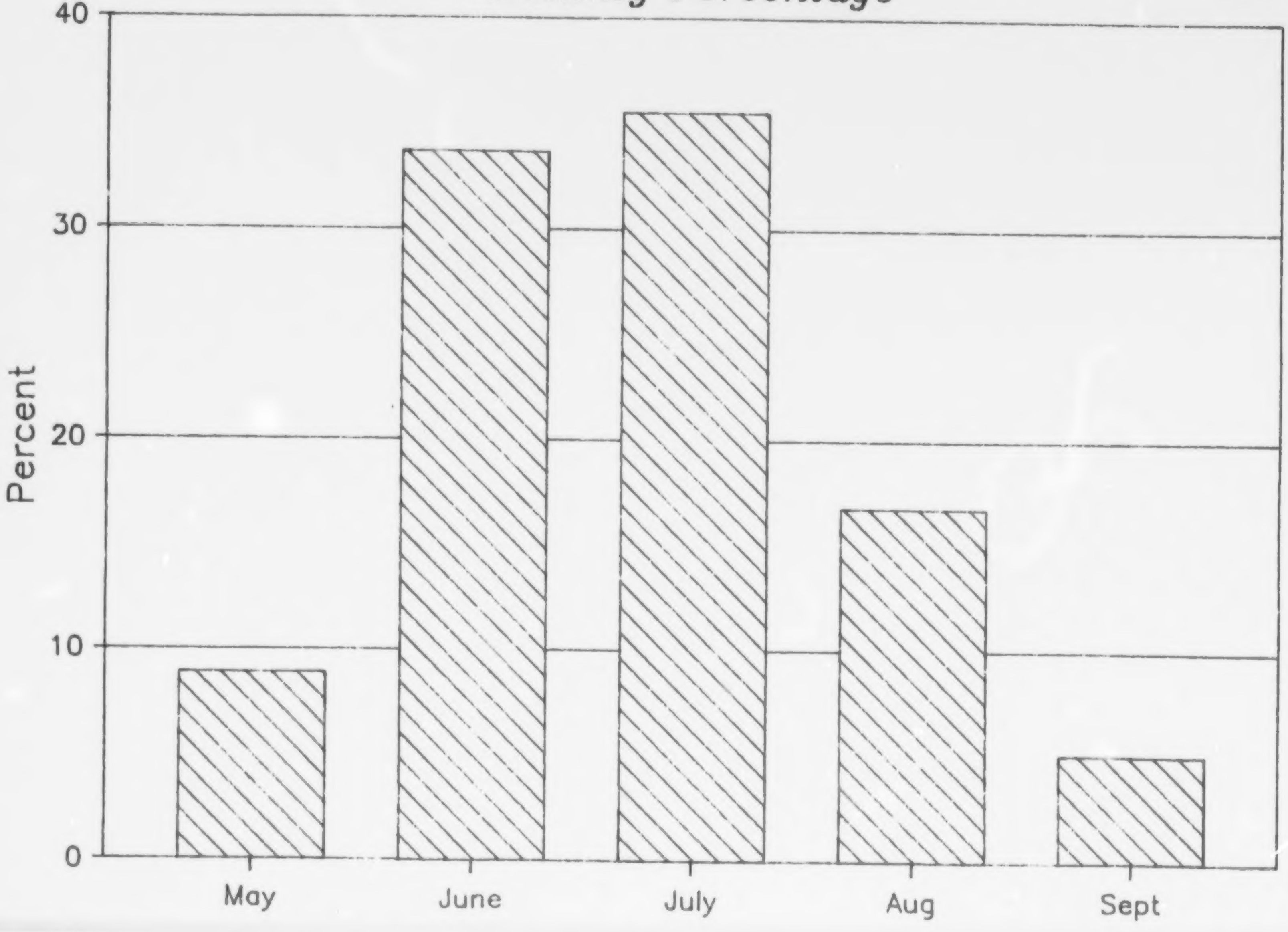


Figure 3.5

The manner in which water was allocated to irrigation is consistent with current water allocation guidelines used by Sask Water. It was assumed that 450 mm of water per ha would be allocated to the upland irrigation. This type of development would likely require a canal delivery system for a group project. For the lowland irrigation which could be less intensive with fewer losses and probably comprised of a number of individual projects, the assumed allocation was 300 mm per ha. The manner in which the irrigation use was distributed over the summer is shown on Figure 3.5.

3.3.3.9 Scenarios

To provide an indication of the sensitivity of the hydrologic results to various assumptions, a few different scenarios were simulated. Two assumptions that have considerable impact on the resulcs are the amount of new irrigation that takes place and how the water of the Souris River is shared between Saskatchewan and North Dakota.

Saskatchewan's share could vary between 60 and 50 percent of the annual natural flow depending on the amount of storage in Lake Darling in North Dakota. Consequently, the effect of both 60 percent and 50 percent sharing was simulated. The scenarios that were simulated are shown in Table 3.7.

Table 3.7

SIMULATION SCENARIOS

Scenario No.	Level of Use[1]	New Area Irrigated[2] (ha)	Saskatchewan Share of Annual Natural Flow[3]
1	Foreseeable Future	0	50 percent
2	Foreseeable Future	4,800	50 percent
3	Foreseeable Future	0	60 percent
4	Foreseeable Future	4,800	60 percent

1) Quantities specified in Table 3.5 including the requirement for the proposed thermal electric generating station..

2) 2,000 ha as lowland irrigation supplied from Rafferty and 1,200 ha as lowland irrigation supplied from Alameda; 1,600 ha as upland irrigation from Alameda.

3) The percentage share of the annual natural flow of the Souris River that Saskatchewan is entitled to use.

3.3.4 Water Supply Results

The model application for each scenario produced for the historic period of record a set of simulated monthly elevations for each modelled reservoir and monthly mean channel flows for the various river reaches modelled.

The results are presented by scenario. For each of the four scenarios, a set of results is presented as:

- monthly reservoir elevation plots for Rafferty and Alameda; and,
- upper quartile, median and lower quartile monthly flows for Souris River below Long Creek (model channel 116), Moose Mountain Creek below Alameda Reservoir (model channel 102) and Souris River at the International Boundary (model channel 100).

Annual volumes of flow for the locations identified above are shown for scenarios 2 and 4. The results that are presented reflect a situation where certain water demands were always met. Based on the modelling assumptions employed, there were no water supply shortages experienced for: foreseeable future water requirements as supplied from Rafferty and Alameda; apportionment; and, the Shand generating station. Annual shortages to new irrigation occurred in up to 30 percent of the years. However, this frequency of shortage is consistent with the guidelines used by Sask Water to allocate water to irrigation. These guidelines and their implications are discussed in the EIS chapter on irrigation.

Because of the large number of figures, only the results from scenario 4 are presented in this chapter. The basic results from the other scenarios are included in Appendix B. In Chapter 4, the results from all of the scenarios are discussed with a view to showing the potential change in hydrologic conditions from pre to post-project conditions. In addition, in Chapter 4, the April and August flow conditions over the historic period are depicted with flow duration curves.

Scenario 4 shows the impact of the full irrigation development of 4,800 ha under conditions of allowing a minimum of 40 percent of the annual natural flow of the basin to flow to North Dakota.

The hydrologic impacts on the reservoirs are demonstrated by the continuous plot of month-end elevations on Rafferty and Alameda Reservoirs on Figures 3.6 and 3.7. The maximum elevation reached on both reservoirs is the maximum allowable flood level. In years when that occurs the water is released as soon as possible, but so as not to cause flooding problems downstream, to get the reservoirs down to their full supply levels.

Figures 3.8 to 3.10 show the total annual volume of flow at the specified location. At the border (Figure 3.10) the volumes represent, in most years, the minimum volume of natural flow that North Dakota is entitled to, which in this scenario is 40 percent; however, in some years, more than the entitlement flows to North Dakota because of spills at Rafferty and Alameda and/or because of large amounts of runoff from the portion of the basin below the reservoirs. The volume depicted on Figure 3.9 basically represents releases from Alameda Reservoir. The volumes on Figure 3.8 represent the combination of releases from Rafferty Reservoir and spills at Boundary Reservoir. These flows include releases for lowland irrigation.

Figures 3.11 and 3.13 show the lower, median and upper quartile monthly mean flow at three locations. These values were determined respectively as the monthly mean flow equalled or exceeded 75, 50 and 25 percent of the time over the simulated 1912 to 1981 period.

These figures depict potential flow distribution in a very general sense. By comparing the plots for each scenario at a particular location the potential effect of lowland irrigation development and apportionment (meeting 50 percent as compared to meeting 40 percent) can be determined.

It should be noted that by depicting the flows in this manner, flows from month to month are independent. For example, the upper quartile flows for each month would not necessarily occur in combination. If an upper quartile flow occurred in May, it would not necessarily be followed in that year by an upper quartile June flow, so the plots do not represent continuous annual hydrographs.

On the Souris River below Long Creek the effect of lowland irrigation on channel flows can be determined by comparing the plots for scenarios 1 and 2 (Appendix B). Under scenario 2 conditions, the lower quartile and median flow are very similar during the summer period as a result of releases out of Rafferty to irrigate 2,000 ha of land.

Scenario 2 for Moose Mountain Creek shows that although an attempt is made to supply water to irrigate 1,200 ha of lowlands, the lower quartile flows tend to be close to zero. This occurred because Alameda must supply water to meet apportionment in most years and consequently water is at times unavailable for irrigation. In those years, additional releases must be made from Rafferty Reservoir to meet the entire lowland irrigation water demand.

For all these locations, the plots generally show that flows in the late fall and early winter tend to be larger than the early fall values. This occurs because in the modelling annual apportionment deficits were made up as late as possible (even in December). It is a characteristic of the model alogorithims that the deficit could not be completely satisfied earlier. In reality, any special releases required for apportionment would be made, if possible, prior to October 1st of each year.

Comparing the plots for scenarios 1 and 3 shows the effect on operation of the reservoirs of having to meet different apportionment requirements. Basically, the operation of Rafferty is unaffected since the monthly flows are approximately the same for both scenarios. However, below Alameda Reservoir, the median and upper quartile summer releases are higher in scenario 3 to pass 50 percent of the natural flow as compared to scenario 1 where only 40 percent of the natural flow was passed to North Dakota.

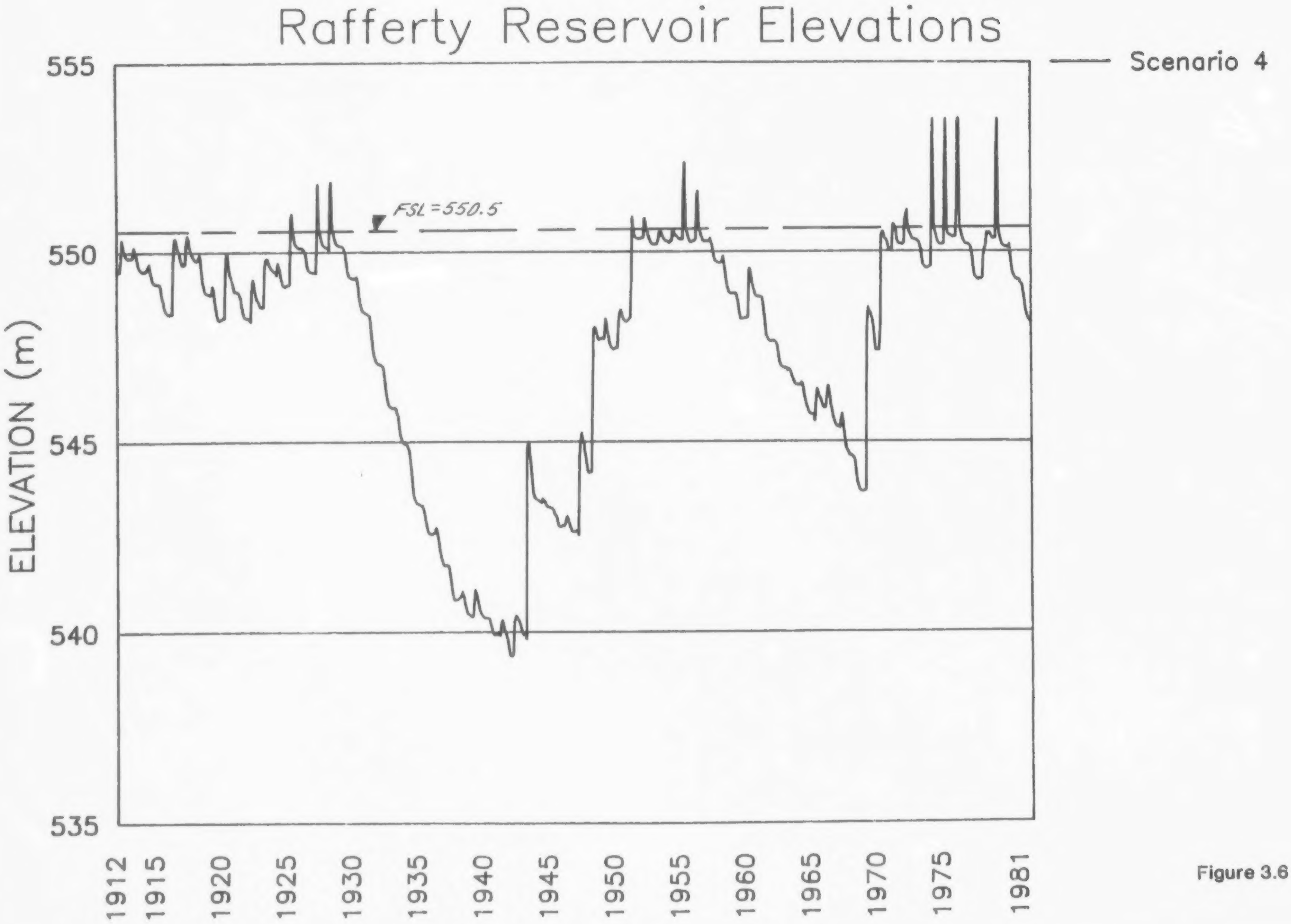

Rafferty Reservoir Elevations
— Scenario 4
FSL=550.5
ELEVATION (m)
555
550
545
540
535
1912
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1981

Figure 3.6

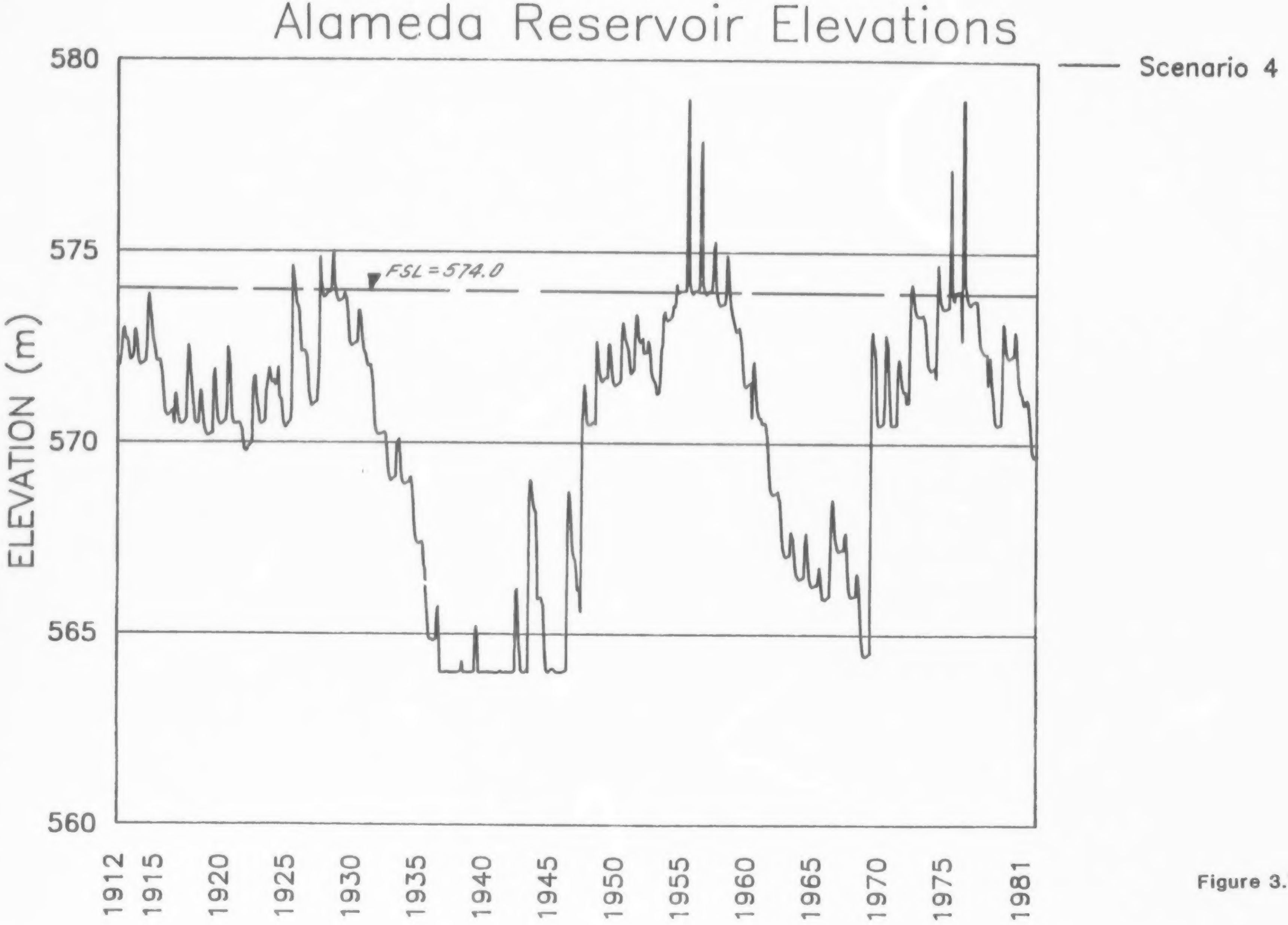
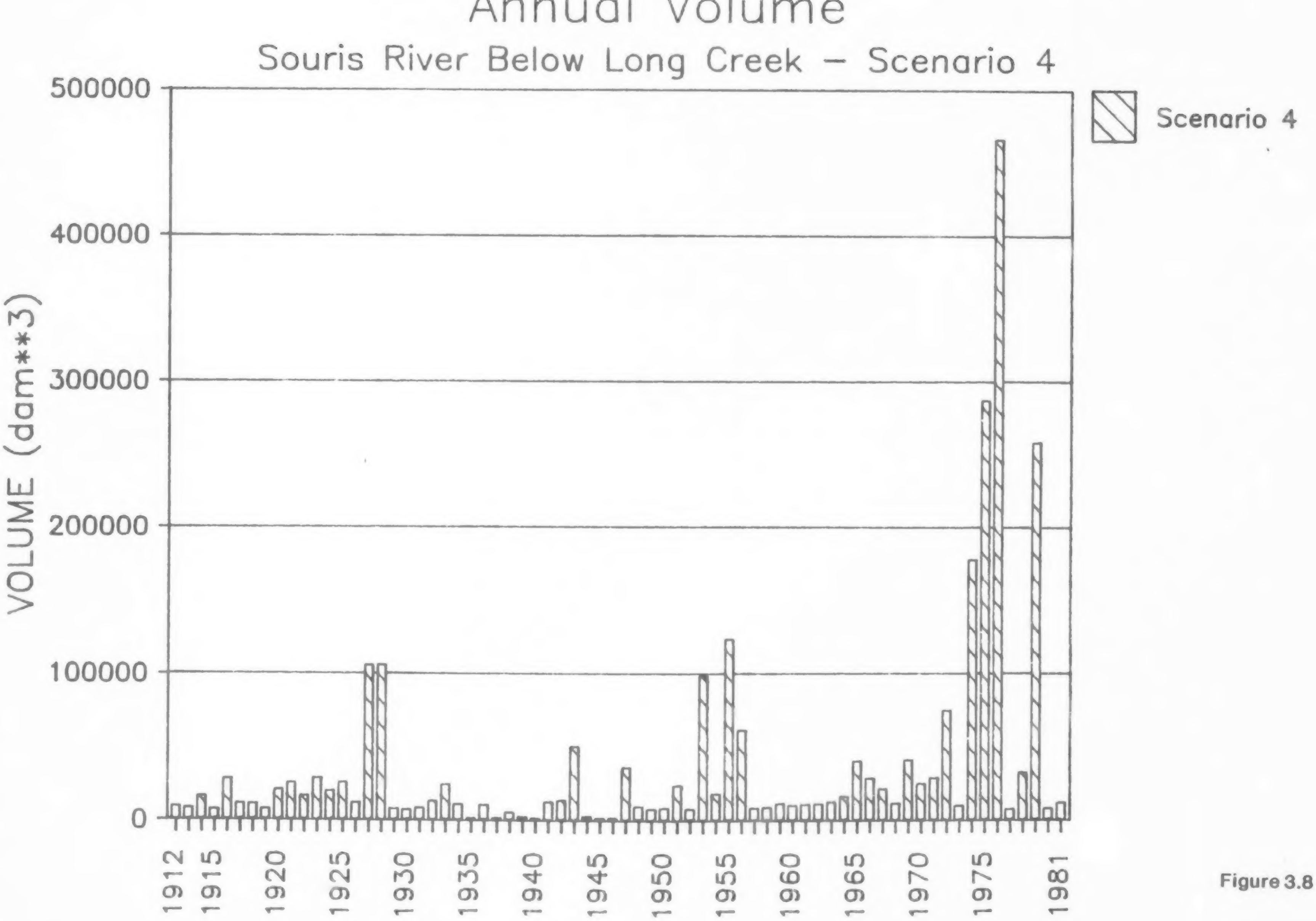

Alameda Reservoir Elevations
— Scenario 4
ELEVATION (m)
580
575
570
565
560
FSL = 574.0
1912
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1981

Figure 3.7



Annual Volume

Souris River Below Long Creek – Scenario 4

Figure 3.8

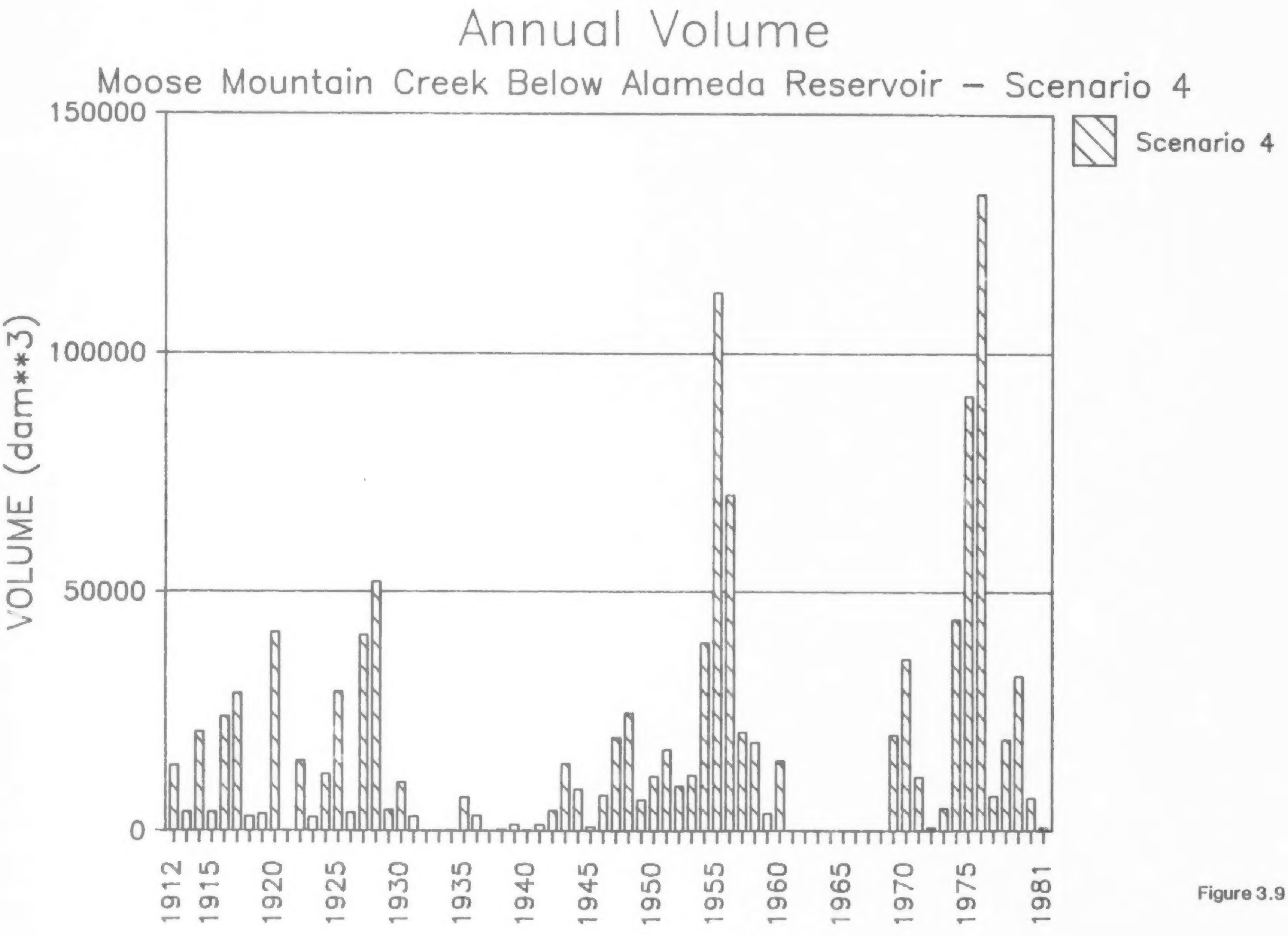

Annual Volume
Moose Mountain Creek Below Alameda Reservoir – Scenario 4
Scenario 4
VOLUME (dam**3)
150000
100000
50000
0
1912
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1981

Figure 3.9

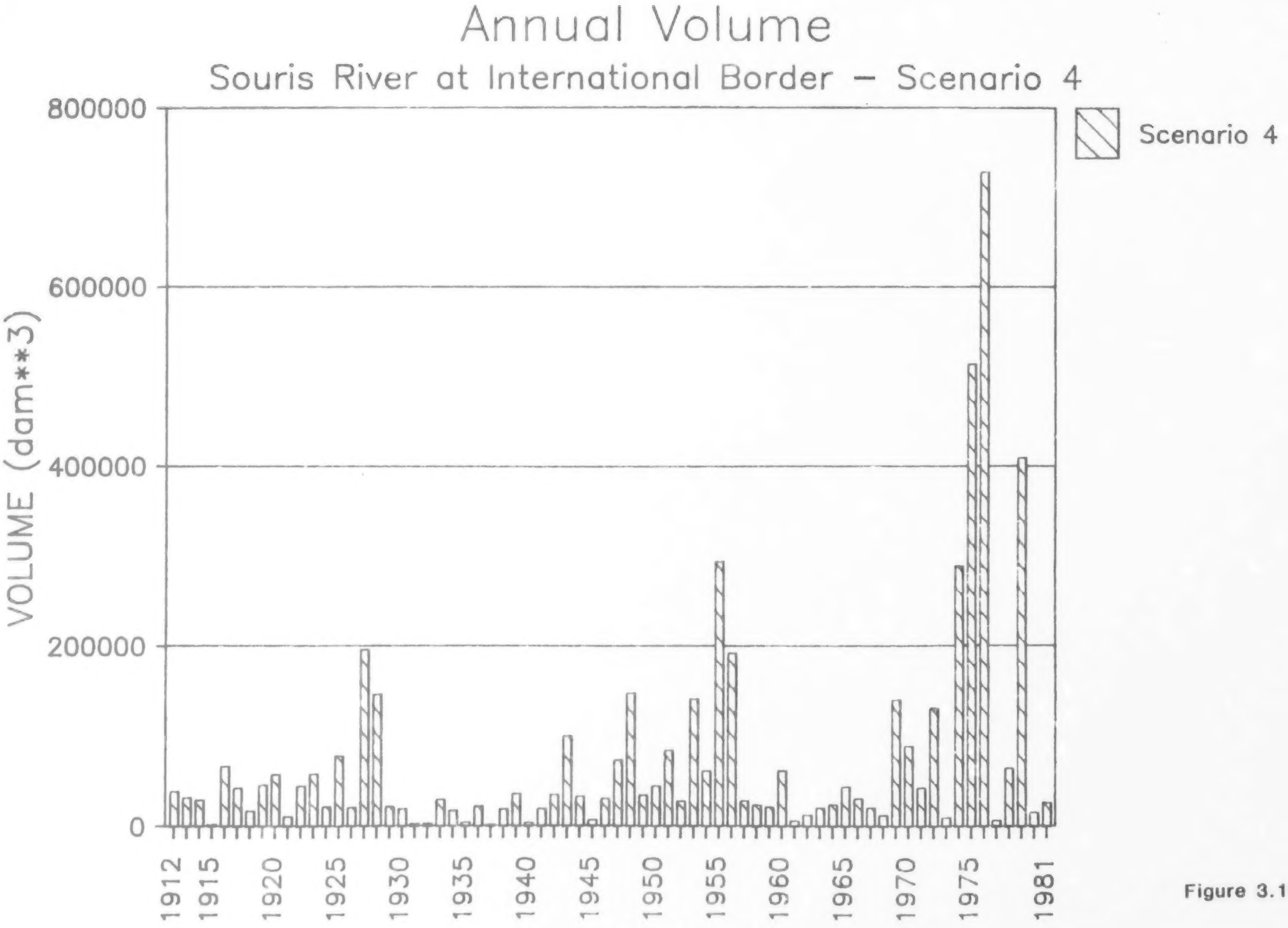
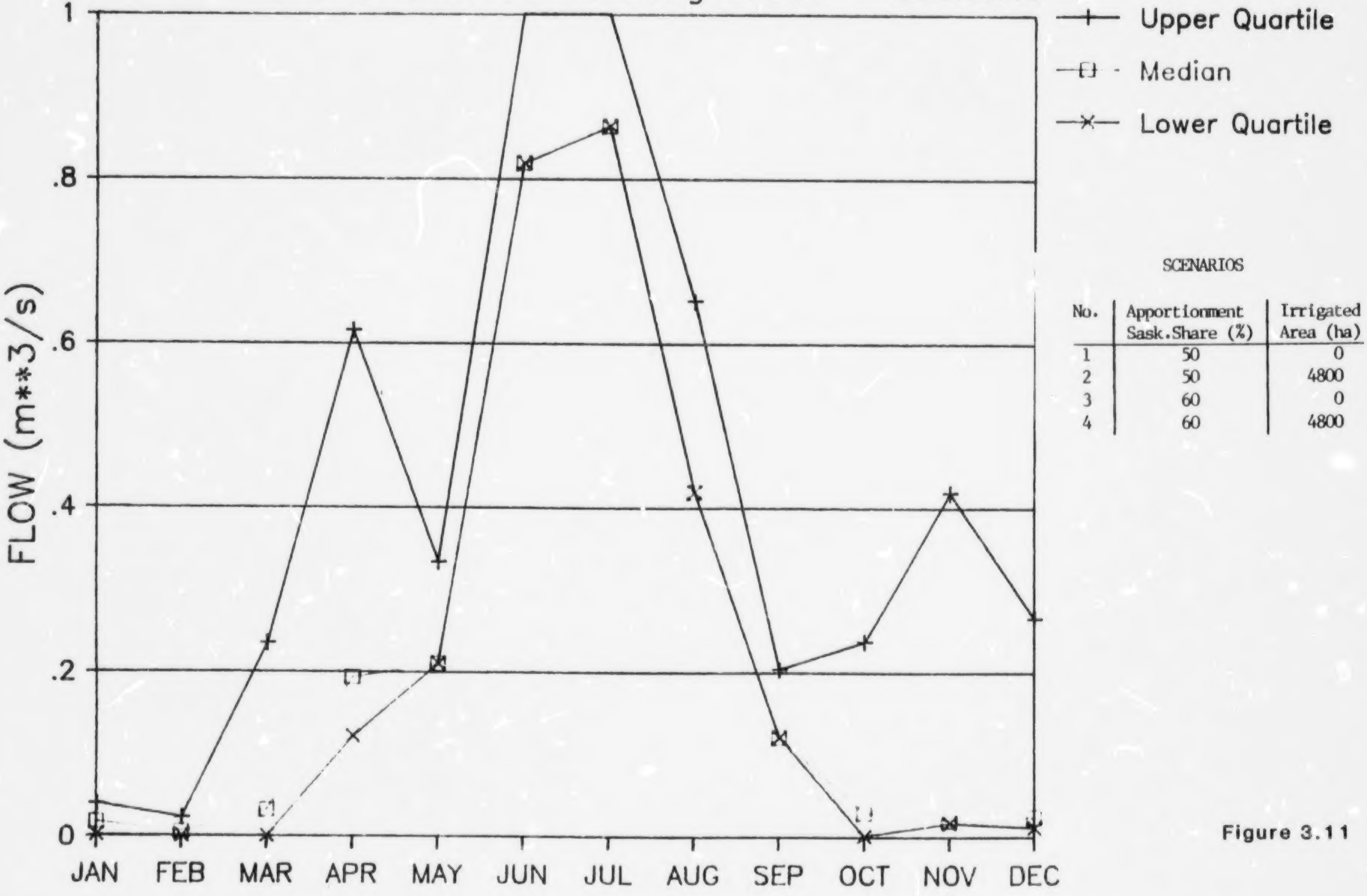

Annual Volume
Souris River at International Border – Scenario 4
Scenario 4
VOLUME (dam**3)
800000
600000
400000
200000
0
1912
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1981

Figure 3.10



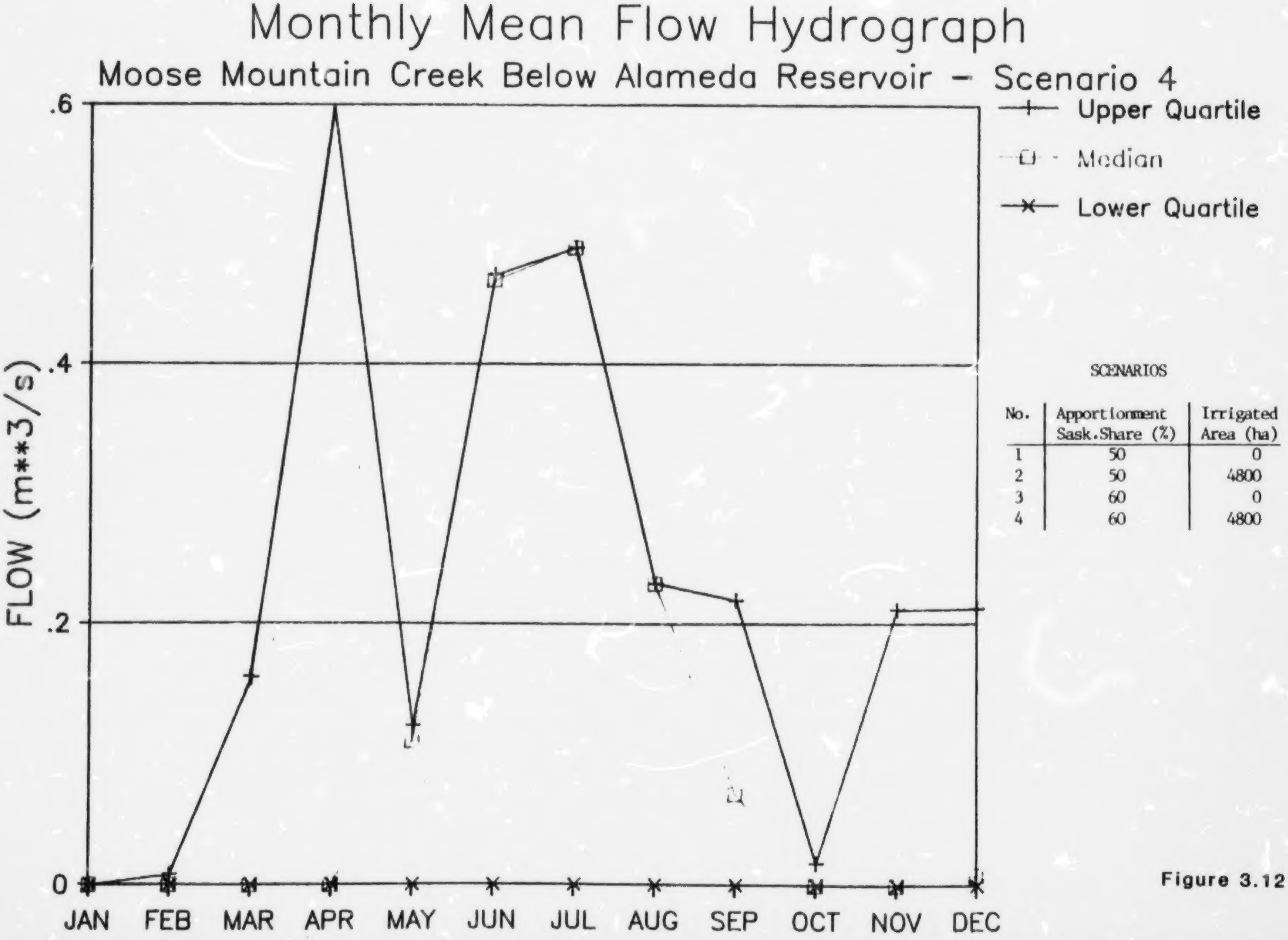
Monthly Mean Flow Hydrograph

Souris River Below Long Creek – Scenario 4

SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

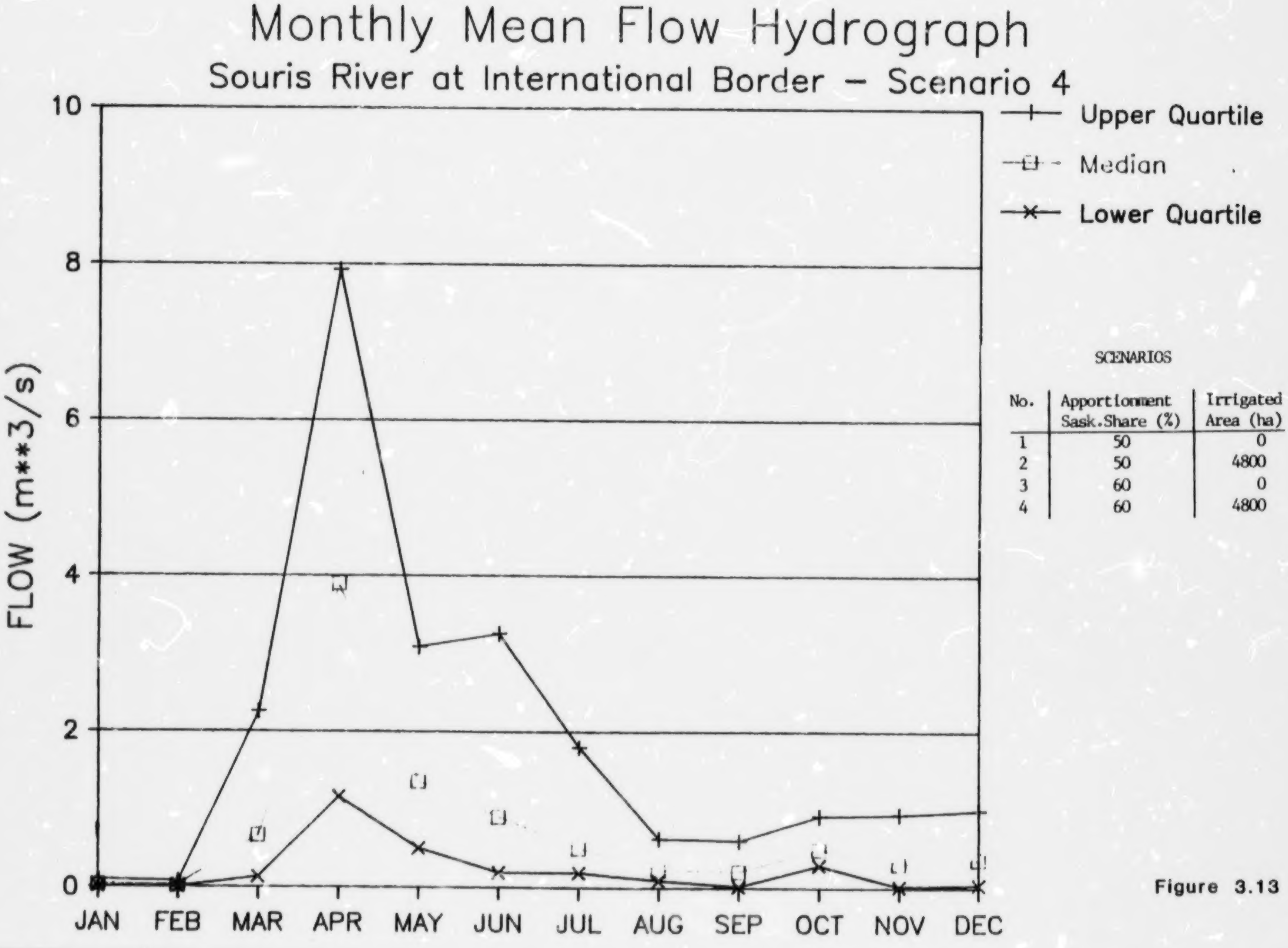
Figure 3.11



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure 3.12



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure 3.13

3.4 RESERVOIR TIME TO FILL

The computer model simulations all assumed that Rafferty and Alameda would start the simulation period nearly full and the amount of water use assumed for the scenario would commence in the first year and continue at the same level until the end of the period (1912-1981). As indicated previously this assumption was used to demonstrate the impact of the project in the long term. In reality, during the initial years of filling, water use will likely increase gradually. Also new irrigation use will not likely be permitted from Rafferty Reservoir until Rafferty Reservoir has achieved a certain minimum elevation probably in the vicinity of 543.5 metres.

Based on an analysis of historical stream flow data, it is recognized that the runoff potential is highly variable from year to year and that there are periods of successive years when above average or below average flows occur. Consequently, a firm estimate cannot be made of when the reservoirs will reach their respective full supply levels.

However, historical records of runoff can be used in conjunction with assumptions regarding amount of water use to establish a relationship between reservoir elevation, time and probability. This has been done and the results expressed in the graphs shown on Figures 3.14 and 3.15 for Rafferty and Alameda Reservoirs. The assumptions used to develop each of these graphs are consistent with those of scenario 4 and are as follows:

(a) evaporation loss on the reservoirs and existing and foreseeable future use are accounted for;

(b) Alameda Reservoir is used primarily to meet the requirements for apportionment;

(c) water is supplied from both reservoirs to meet the requirement of 4,800 ha of new irrigation. All assumptions for operations used in the water supply modelling were accounted for in the probability of fill simulations including not allowing diversions from Rafferty for new irrigation use until Rafferty reached elevation 543.5 metres;

and,

(d) water is supplied from Rafferty for the Shand thermal electric generating station.

The following example question is provided to assist in interpretation of the graphs:

> "What is the probability of Rafferty Reservoir reaching elevation 547.0 m within five years after completion of construction?"

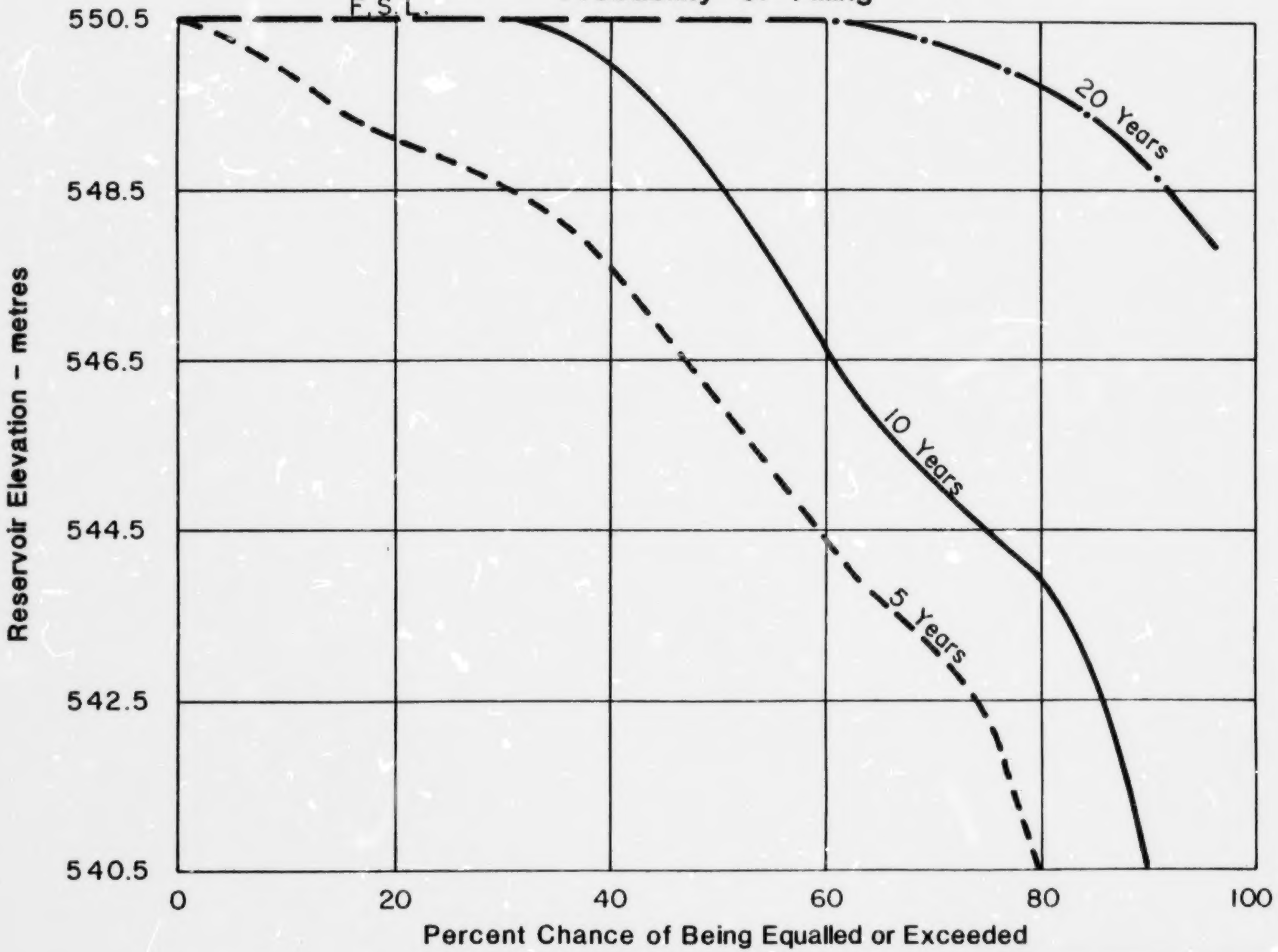
The answer is found on Figure 3.14, by finding the intersection of a horizontal line marking elevation 547.0 metres and the plotted line identified as "five years." At the intersection point the probability can be read from the bottom axis as the percent chance of being equalled or exceeded. There is a 45 percent chance of equalling or exceeding elevation 547.0 m on Rafferty Reservoir with five years after completion of construction under scenario 4 assumptions.

3.4.1 Operations During Fill Period

Once Rafferty Dam has been constructed it will take a number of years to fill the reservoir. During that fill period water will likely be made available in accordance with guidelines that have been prepared by Sask Water. These are described in Appendix C. During this fill period the priorities for water allocation will be generally the same as described previously for the water supply modelling.

RAFFERTY RESERVOIR

Probability of Filling



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Recommended by
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SASKATCHEWAN WATER CORPORATION

Date May 7, 1987
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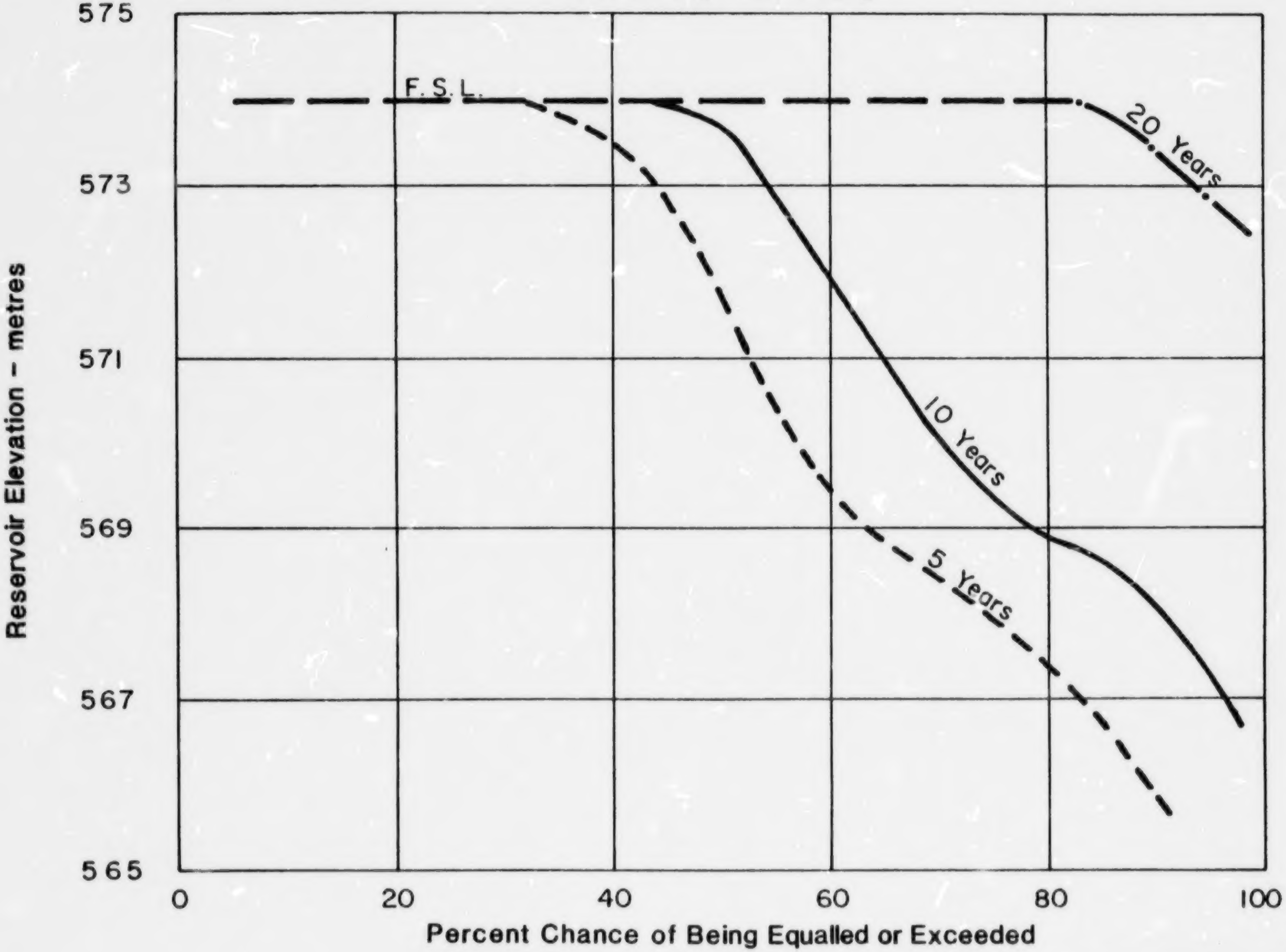
Figure 3.14

ALAMEDA RESERVOIR

Probability of Filling



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Recommended by
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SASKATCHEWAN WATER CORPORATION

Date May 7,1987
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Figure 3.15

3.5 FLOOD CONTROL

3.5.1 General

The flood control capability of Rafferty and Alameda Reservoirs was modelled with the U.S. Army Corps of Engineers, HEC-5 computer model. The 1:50, 1:100 and 1:500 inflow hydrographs were developed for Rafferty, Alameda and Boundary Reservoirs and for the contributing area between the reservoirs and the international border. Using the HEC-5 model, these inflow hydrographs were routed through the reservoirs and the resultant outflows routed down the channels to estimate the 1:50, 1:100 and 1:500 flood peaks at various downstream locations. Simulated flood conditions can be obtained from the model in terms of daily reservoir elevations and daily flows in the various reaches of the Souris River downstream of the reservoirs.

3.5.2 HEC-5 Computer Model

The program was developed at The Hydrologic Engineering Center, of the U.S. Army Corps of Engineers. The initial version was written for flood control operation of a single flood event and was released as HEC-5, "Reservoir System Operation for Flood Control," in May, 1973. The program was then expanded to include operation for conservation purposes and for period-of-record routings.

The program was developed to assist in planning studies for evaluating proposed reservoirs in a system and to assist in sizing of works for flood control and conservation storage requirements for projects. The program should also be useful in selecting the proper reservoir releases throughout the system during flood emergencies in order to minimize flooding as much as possible and yet empty the system as quickly as possible while maintaining a balance of flood control storage among the reservoirs.

The above purposes are accomplished by simulating the sequential operation of a system of reservoirs of any configuration for short interval historical or synthetic floods or for long duration non-flood periods or for combinations of the two. Specifically, the program may be used to determine:

(a) Flood control and conservation storage requirements for each reservoir in the system.

(b) The influence of a system of reservoirs on the spatial and temporal distribution of runoff in a basin.

(c) The evaluation of operation criteria for both flood control and conservation (including hydropower) for a system of reservoirs.

(d) The expected annual flood damages, systems costs and system net benefits for flood damage reduction.

(e) The system of existing and proposed reservoirs or other alternatives including nonstructural alternatives that results in the maximum net flood control benefits. This is accomplished by making simulation runs for selected alternative systems.

The general capabilities and limitations of the program are as follows:

(i) Configuration of System

(a) Any reservoir system configuration may be used as long as dimension limits are not exceeded for number of reservoirs, number of control points, number of diversions, etc. The system configuration is specified by routing reaches (route from and route to on RT card) and by the required downstream sequential order of input control points.

(b) Reservoirs which have flood control storage may be operated to minimize flooding at any number of downstream control points.

(c) Reservoirs without flood storage will be operated for their own requirements (power or low flow) and can be operated to provide low flow requirements for any number of downstream control points.

(d) Reservoirs in the system that operate for a common control point are kept in balance (in terms of reservoir level - RL cards - for both flood and conservation operation) as much as possible.

(ii) Reservoir Description

(a) Each reservoir must have a starting storage and storage values for each target level. Target levels which specify the allocation of storage for flood control and conservation (power and/or water supply) purposes can vary monthly or remain constant.

(b) Each reservoir operates for itself and as many downstream points as desired.

(c) Each reservoir must have a table of outlet capacities as a function of reservoir storages.

(d) Each reservoir is also considered a control point and requires control point data.

(e) Additional data on reservoir areas, elevations, diversions and costs can be given as a function of reservoir storages.

(iii) Control Point Description

(a) Each control point must have an operating channel capacity. The channel capacity can be constant, or vary monthly, or vary with channel flows at any location, or vary with reservoir levels at any reservoir.

(b) Each control point can have low flow requirements (minimum desired and/or minimum required) which are constant, or vary monthly, or vary period by period.

(c) Each control point can have a stage-discharge rating curve for determining regulated and natural stage hydrographs.

(d) Each control point is linked to the next downstream point by specifying the channel routing reach.

(e) Additional data on elevation (or channel storage) versus discharge can be given for the channel.

(iv) Flow Data

The program normally uses incremental local flows (flows between adjacent control points) in the system routings.

(v) Stream Routing

(a) The following stream routing methods are available: Straddle-Stagger, Tatum, Muskingum, Modified Puls and Working R&D.

(b) Each routing reach may be subdivided into several steps. Routine criteria for natural flow conditions can also be specified.

(c) For each routing reach, two sets of flood routing criteria (at least one linear) can be specified along with the applicable routing interval (i.e. 3 hour and 12 hour).

(d) When reservoir releases are routed by nonlinear methods (Modified Puls or Working R&D), linear approximations are used to determine the reservoir's releases. The actual releases are then routed by the nonlinear method.

(e) Steady state is assumed for flows prior to the first period of routing.

(vi) Reservoir Routing Options

(a) Accounting Method - when the reservoir release is determined based on desired operation, storage is equal to inflow less outflow plus previous storage less evaporation (if specified).

(d) Surcharge Routing - when the desired release is greater than the physical capacity, an iterative method is used to find the outflow. This method provides the same results as the Modified Puls method.

(c) Emergency Releases - when the desired release for the current period plus channel capacity releases for future periods (up to the limit of foresight specified) would cause a reservoir to exceed maximum flood storage in the current or future periods, a release can be made for the current period so that the reservoir does not exceed the top of flood pool in the near future.

(vii) Reservoir Operation

(a) Outflow can be specified for any number of reservoirs for any or all time periods (providing the outlet capacity is greater than the specified release) and the program will adjust other reservoir releases as necessary; otherwise, the program will determine all reservoir releases.

(b) For printout purposes, uncontrolled cumulative local flows (flow below all upstream reservoirs) do not include flows from upstream reservoirs if one acre-foot or more of flood control storage is used; otherwise, uncontrolled local flows will include flows from the upstream reservoir drainage areas.

(c) In addition to flood control operation, conservation operation may be specified to provide minimum flows at one or more downstream locations, for two levels of dependability (desired and required), based on reservoir storage.

(viii) Reservoir Releases

Reservoir releases can be based on channel capacity, minimum flow requirements, amount of reservoir storage, outlet capacity or specified release rates.

3.5.3 Model Application

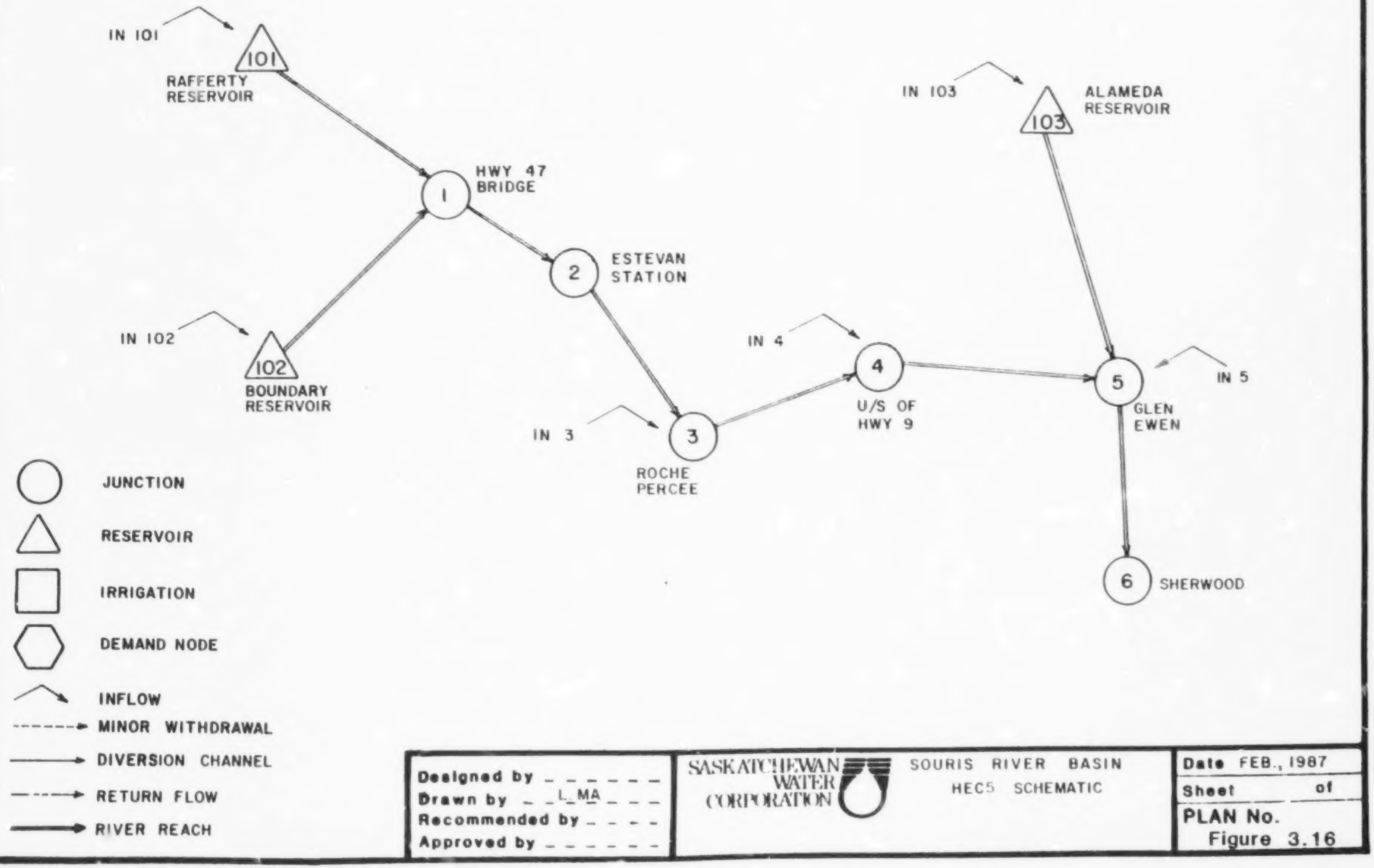
3.5.3.1 Flood Hydrographs

Theoretical flood hydrographs for the 1:50, 1:100 and 1:500 flood flows were derived for the following locations:

- Souris River at Rafferty Reservoir.
- Long Creek at Boundary Reservoir.
- Moose Mountain Creek at Alameda Reservoir.
- Souris River at Roche Percee.
- Souris River at Oxbow.
- Souris River at Glen Ewen.
- Souris River at Sherwood.

The locations of these inflows are shown on the basin schematic on Figure 3.16.

Using recorded data, statistical estimates can be made of the 1:50, 1:100 and 1:500 flood peaks and volumes at any of the locations described above. However, because of the need to develop an operating plan that could meet certain flood control objectives in North Dakota, it was decided to use the flows recorded at the border as the basis for determining the magnitude of flood event that occurs in Saskatchewan. This assumption required the following approach:



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Drawn by L. MA
Recommended by
Approved by

SASKATCHEWAN WATER CORPORATION

SOURIS RIVER BASIN
HEC5 SCHEMATIC

Date FEB., 1987
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PLAN No.
Figure 3.16

(a) Develop the estimated flood peaks and volumes for the 1:50, 1:100 and 1:500 flood events for the hydrometric station Souris River near Sherwood which is considered to represent flows at the International Boundary.

(b) Select a severe recorded flood event and determine the peak and associated volume for the hydrometric station Souris River near Sherwood and, for each event, determine the ratio of the 1:50, 1:100 and 1:500 peak to the peak associated with the selected event.

(c) Develop the 1:50, 1:100 and 1:500 flood hydrographs for each of the desired upstream locations by multiplying each ordinate of the hydrograph recorded at the upstream location during the flood event selected in (b) by the ratio determined in (b).

The hydrographs developed in step (c) above, became the hydrographs that were input to the model to simulate the flood control capabilities of the reservoirs for the desired 1:50, 1:100 or 1:500 event. The flood hydrographs that were selected from the recorded data to develop the 1:50, 1:100 and 1:500 hydrographs were those recorded in 1976.

3.5.3.2 Operating Assumptions

For the three flood events that were studied, the simulated operations were based on the guidelines for flood control provided in section 3.?.1. These guidelines are directed at maximizing the flood control capability of the reservoirs by:

(a) drawing the reservoirs down prior to a forecast flood to provide extra storage;

(b) trying to keep flows within channel banks when possible while trying to minimize the peak flow; and,

(c) trying not to exceed specified target flows at the border which have been identified by the United States as the maximum flows necessary to ensure that the United States can receive flood control benefits commensurate with their financial contribution to the project.

The operation of the reservoirs for flood control has three distinct phases; pre-runoff, runoff and post runoff. The pre-runoff phase would extend from approximately February 1st to March 15th. During this period water would be released from Rafferty and Alameda to lower the reservoirs to provide extra storage for flood control. This drawdown would only be undertaken if the flood forecasts showed that the runoff would be large enough to restore the reservoirs to their full supply levels. The amount of drawdown would depend on the magnitude of flood event that is forecast, channel conditions and a need to keep flows at the border to less than 60 m^3/s during this period.

The operations during the runoff period (March 15th to May 31st) would be based on the flood control guidelines to minimize the downstream peak but would be supported by real time runoff data.

By the end of May, inflow to the reservoirs will have subsided and operation will be directed at lowering the reservoirs to their full supply levels. Depending on the magnitude of the flood event and the amount of pre-flood drawdown achieved there could be water stored in each of the reservoir flood control zones. This water will have to be released in a manner that will keep flows within bank capacity and again not exceed certain target flows at the International Border.

3.5.3.3 Initial Conditions

For each flood event that was modelled, it was assumed that the reservoirs would be approximately one metre below their full supply levels by February 1st of each year.

This is considered a reasonable assumption given the anticipated evaporation losses and level of use that will occur from the reservoirs during the previous year.

3.5.4 Results

The results from the flood control investigations are presented as a series of plots for each of the 1:50, 1:100 and 1:500 flood events of inflow and outflow for Rafferty and Alameda Reservoirs and flow on the Souris River below Long Creek and near Sherwood. The plot for Sherwood represents the flows that would be passed on the Souris River into North Dakota. These plots are shown on Figures 3.17 to 3.24.

It should be noted that all of the plots show flow conditions only up to June 1st. These plots show that the flow at Sherwood will be down to about 11 m^3/s by June 1st. The operating guidelines call for flows at the border not to exceed 11.3 m^3/s for the period June 1st to January 31st. Flows would continue at this rate as a result of reservoir releases until the reservoirs are down to their respective full supply levels. For extreme floods (1:100 and larger) flows at the border would have to continue throughout most of the June to January period to restore Rafferty and Alameda to their full supply levels. At no time would flows have to exceed bank-full capacities in Saskatchewan during that period.

The results are discussed in Chapter 4.

RAFFERTY RESERVOIR

1:50 *Flood Operation*

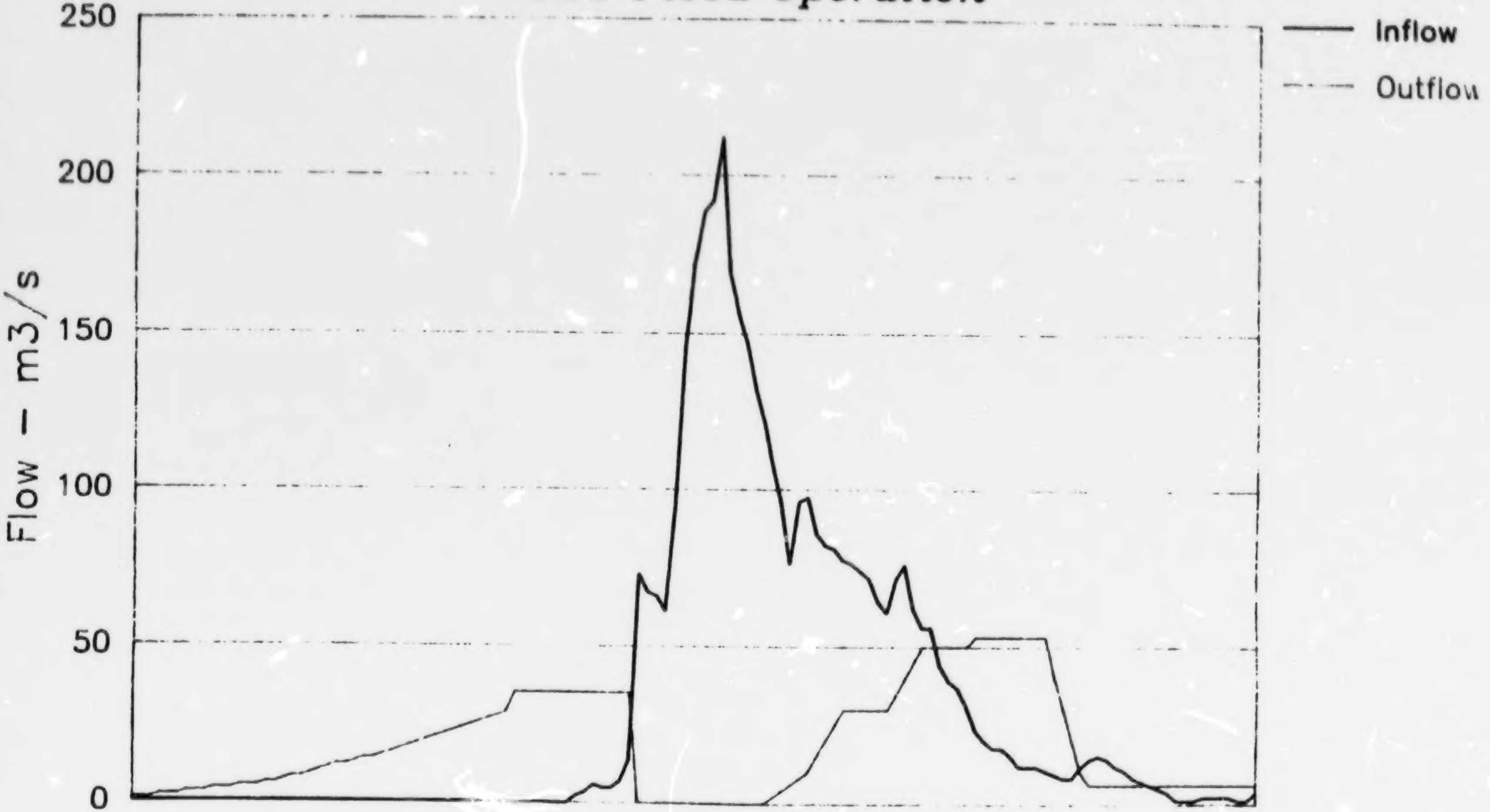


Figure 3.17

RAFFERTY RESERVOIR

1:100 Flood Operation

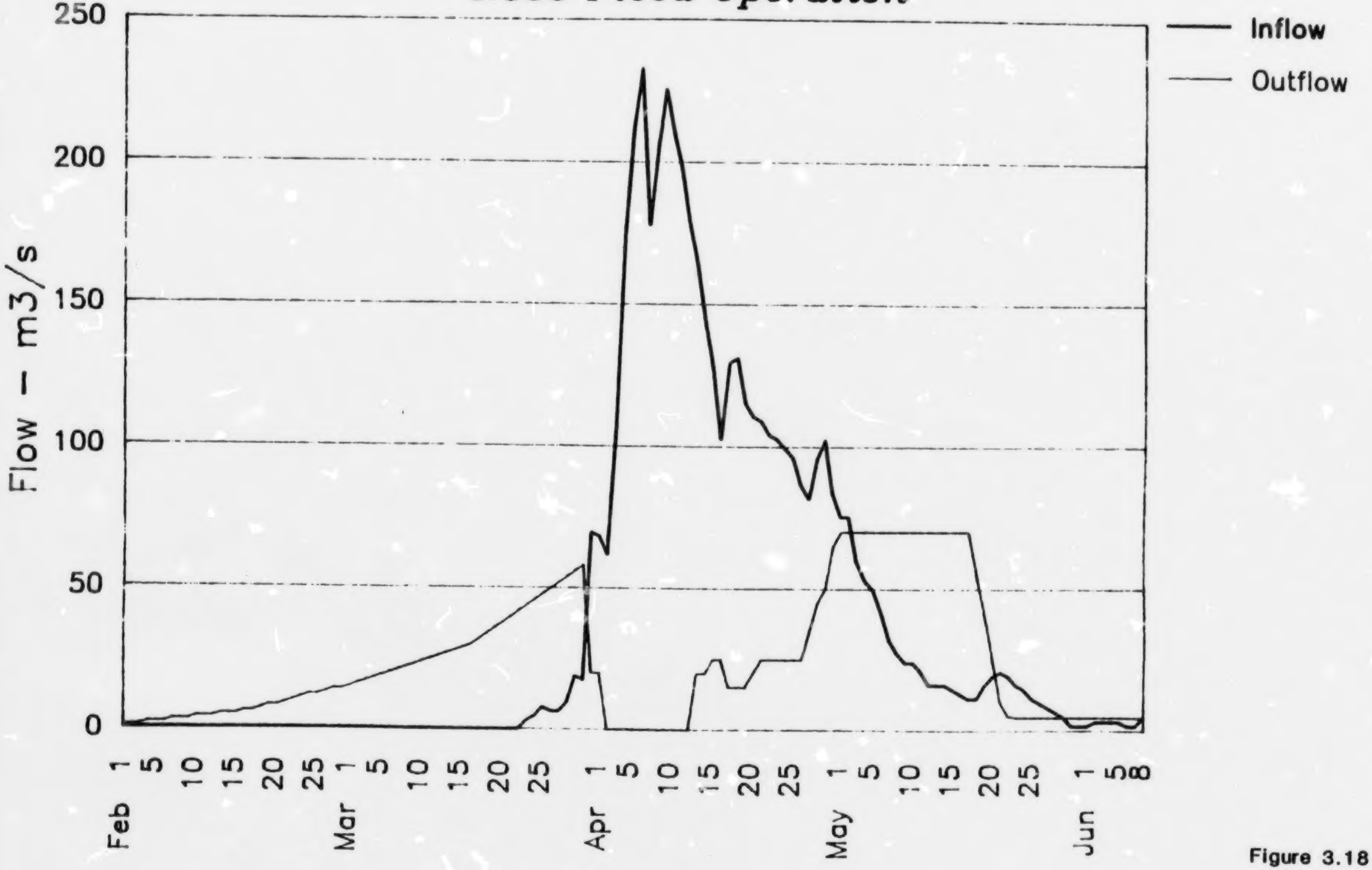
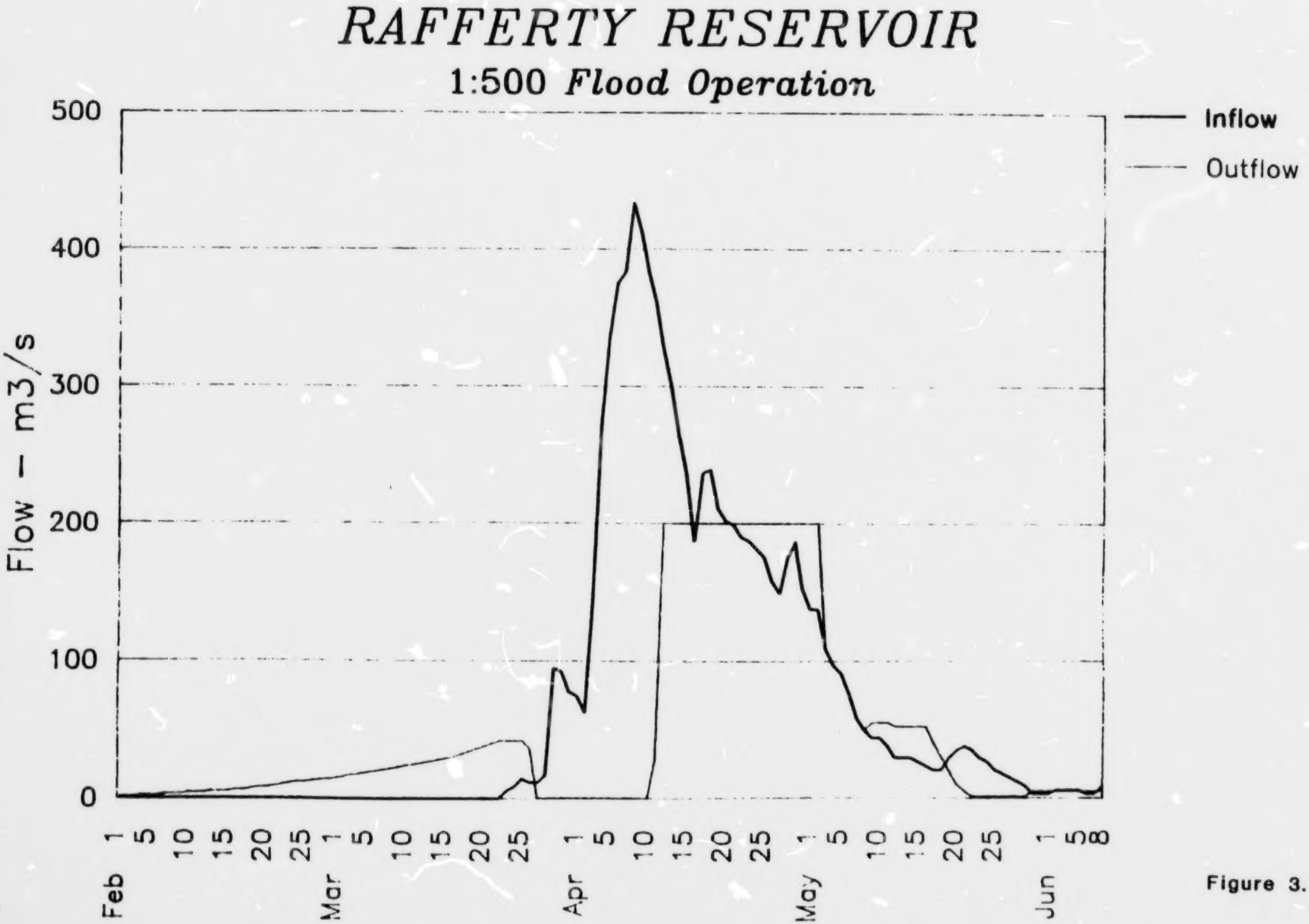


Figure 3.18



RAFFERTY RESERVOIR

1:500 *Flood Operation*

Figure 3.19

ALAMEDA RESERVOIR

1:50 *Flood Operation*

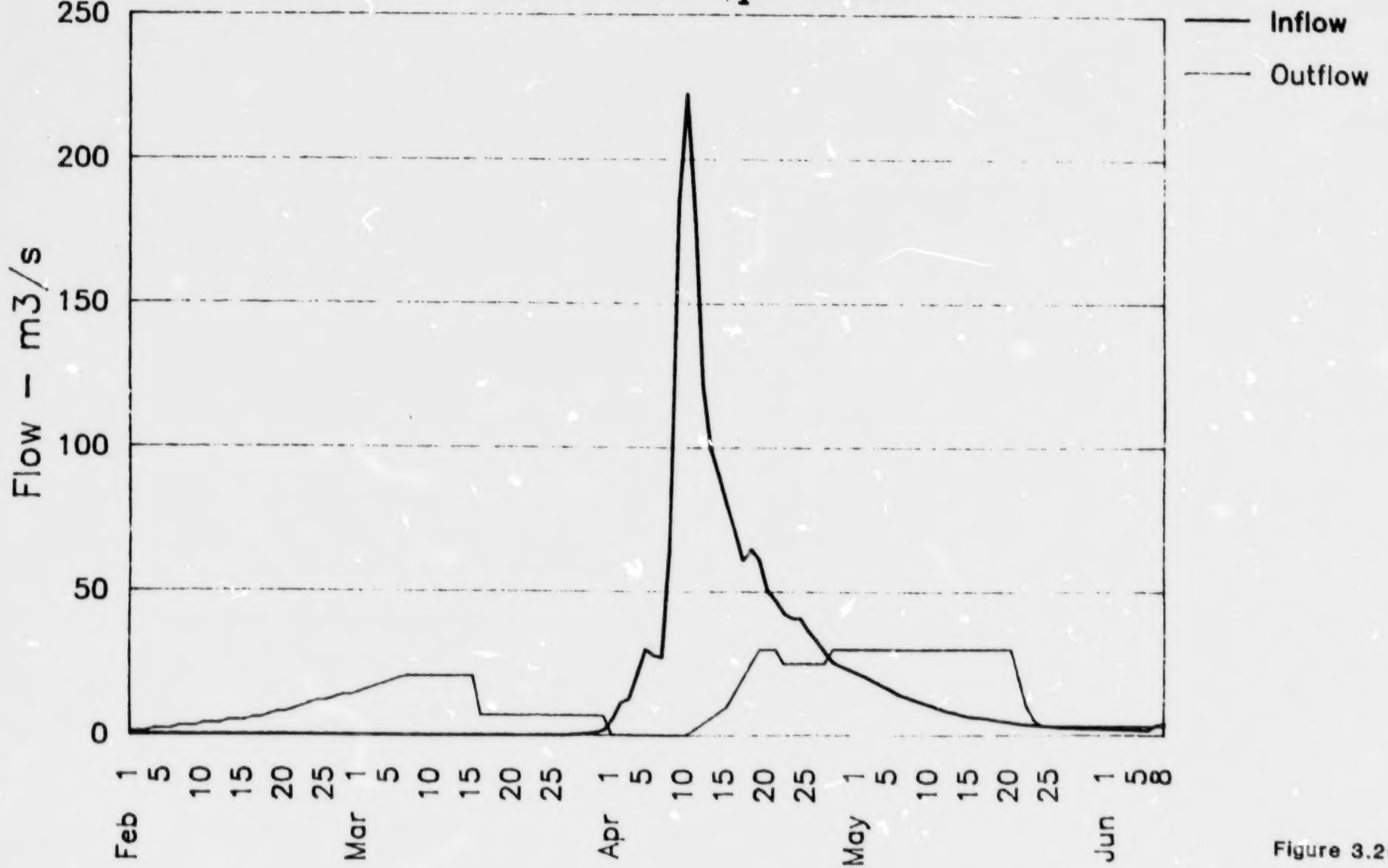
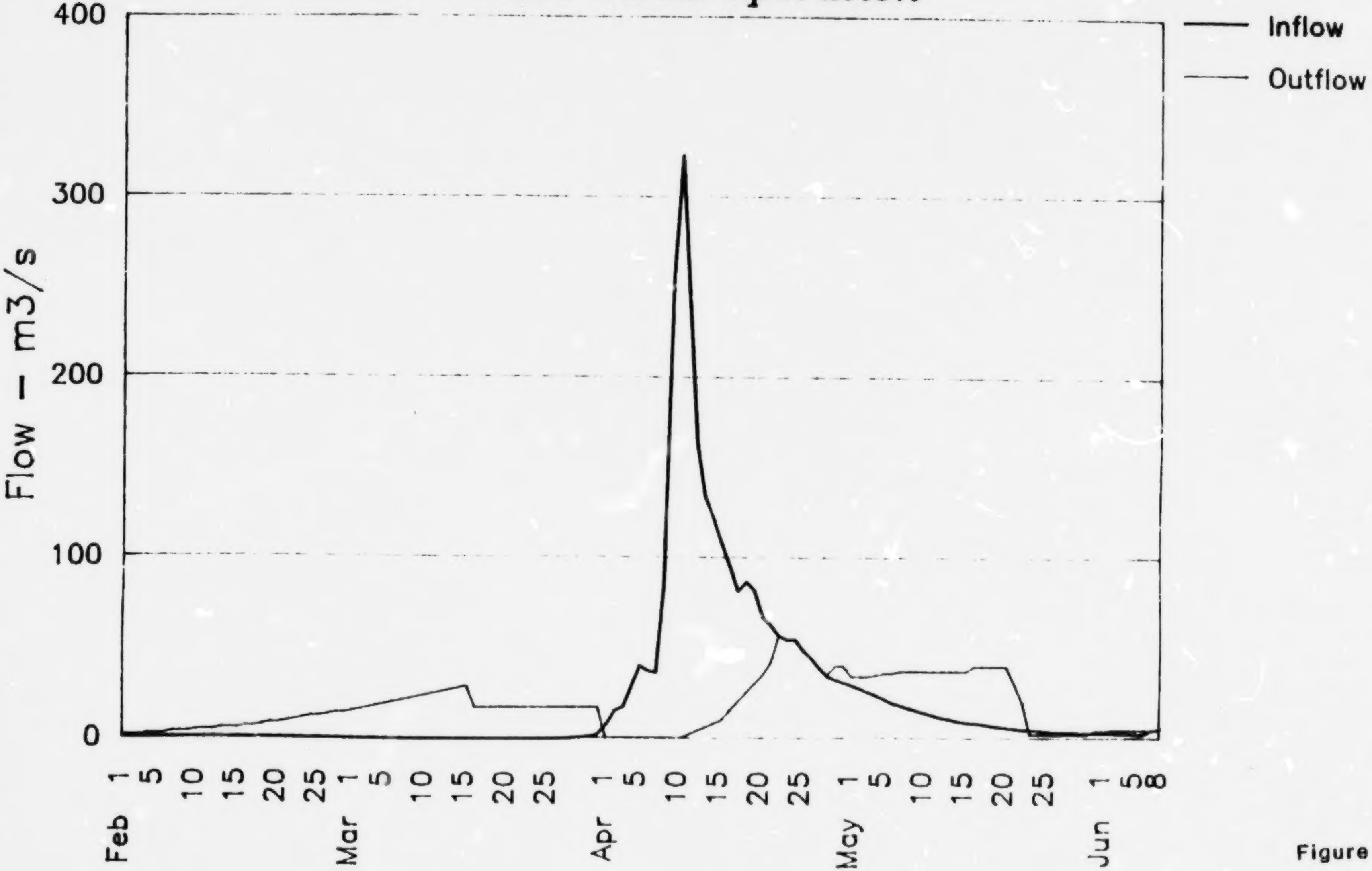


Figure 3.20



ALAMEDA RESERVOIR

1:100 *Flood Operation*

Figure 3.21

ALAMEDA RESERVOIR

1:500 *Flood Operation*

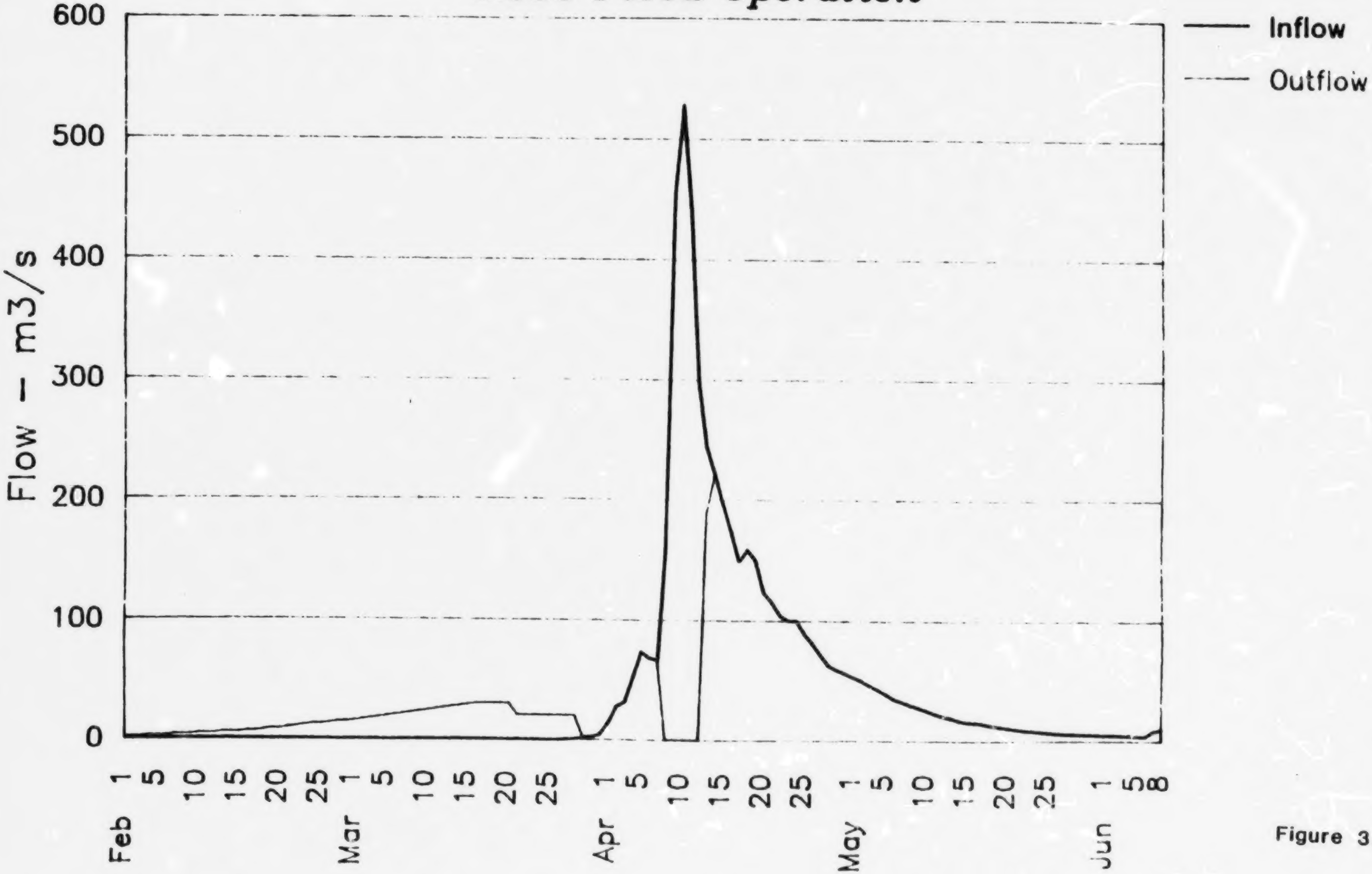


Figure 3.22

POST-PROJECT FLOOD FLOWS

Souris River below Long Creek

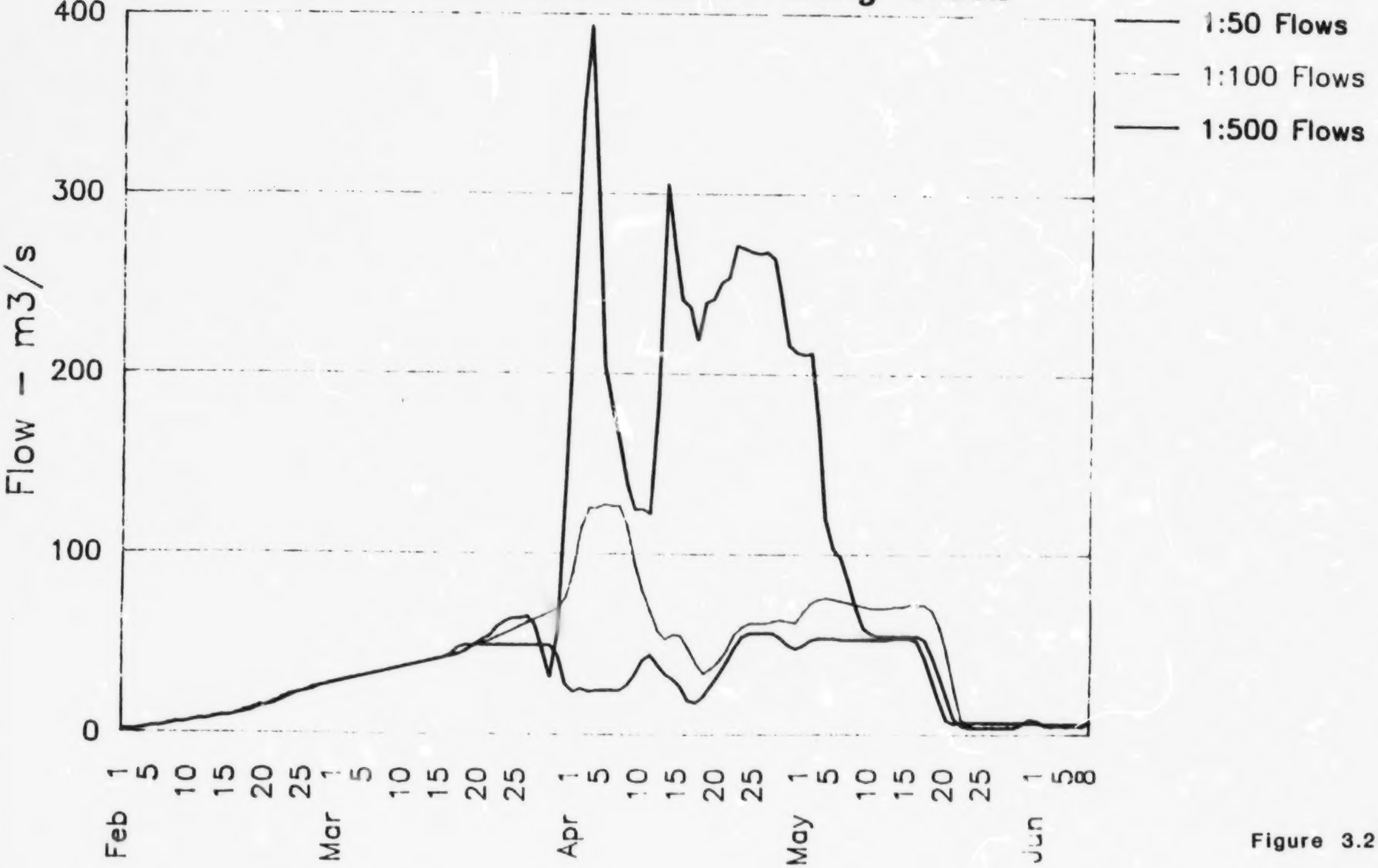


Figure 3.23

POST–PROJECT FLOOD FLOWS

Souris River near Sherwood

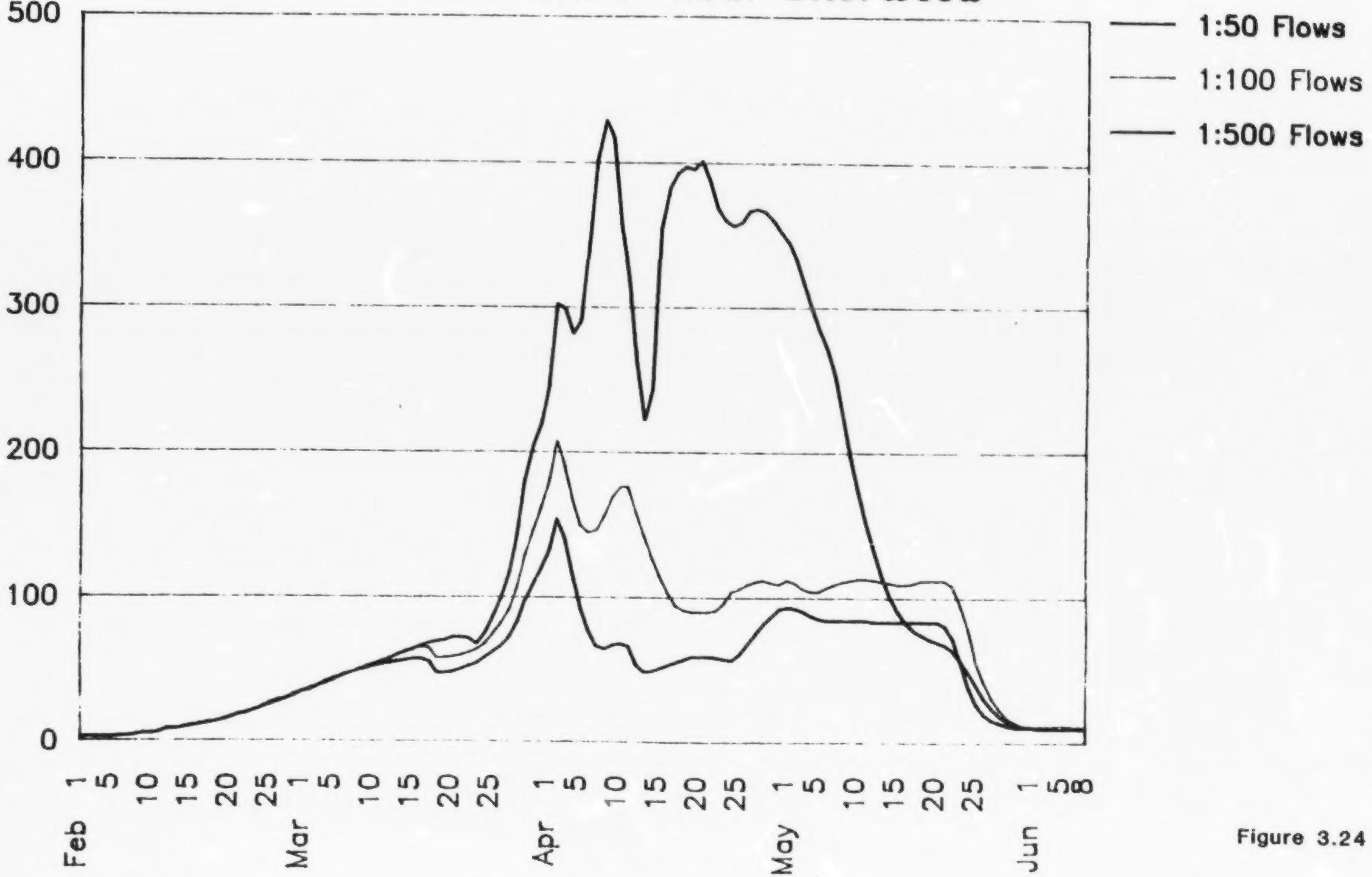


Figure 3.24

CHAPTER 4

HYDROLOGIC IMPACTS

4.1 INTRODUCTION

The impacts that are described in this chapter relate only to changes in potential hydrologic conditions by comparing the existing or pre-project hydrology and post-project hydrology (hydrologic conditions expected after the project is in place). No attempt is made to relate how hydrologic conditions will affect a particular use in physical or economic terms. Also, the impact of possible future drainage of wetlands has not been addressed. Water supply impacts are described in terms of reservoir elevation fluctuations and changes in streamflow at representative locations. Flood control impacts are described in terms of peak flows and duration of flooding downstream of the project, and reservoir inundation during flood events.

To provide the reader with a sensitivity to new irrigation development. There is some discussion of the differences in hydrologic response that are produced with and without new irrigation development.

4.2 WATER SUPPLY

4.2.1 General

Under pre-project conditions there has been limited opportunity for Saskatchewan to utilize very much of its share of the Souris basin water resources. Because of limited storage, Saskatchewan has passed on average, since 1958, approximately 85 percent of the natural flow of the Souris River basin to North Dakota. Figure 4.1 shows that in almost one-third of the years, because of drainage projects that contribute to the Souris River, Saskatchewan has passed in excess of 100 percent of the natural flow.

The development of storage at the Rafferty and Alameda sites will allow Saskatchewan to control, on average, close to one-half of the natural flow of the Souris River basin that originates in Saskatchewan. This means that in most years the reservoirs will be able to retain most of the water to which Saskatchewan is entitled. However, based on the analysis of the results from scenarios 1 and 2 where Saskatchewan attempted to retain 50 percent of the natural flow, in excess of 60 percent was passed on average to the United States. In high runoff years, the reservoirs have a greater likelihood of spilling and the drainage area below the reservoirs tends to contribute more significant amounts of runoff.

4.2.2 Reservoirs

4.2.2.1 Rafferty Reservoir

The computer model simulations show that, after filling, the surface water elevation of Rafferty Reservoir will likely experience successive years of relatively continuous decrease followed by successive years of continuous increase over the long term. The greatest impact will be during periods of extended drought such as was experienced during the 1930's.

SOURIS RIVER near Sherwood

Percent of Natural Flow Historically Passed to United States

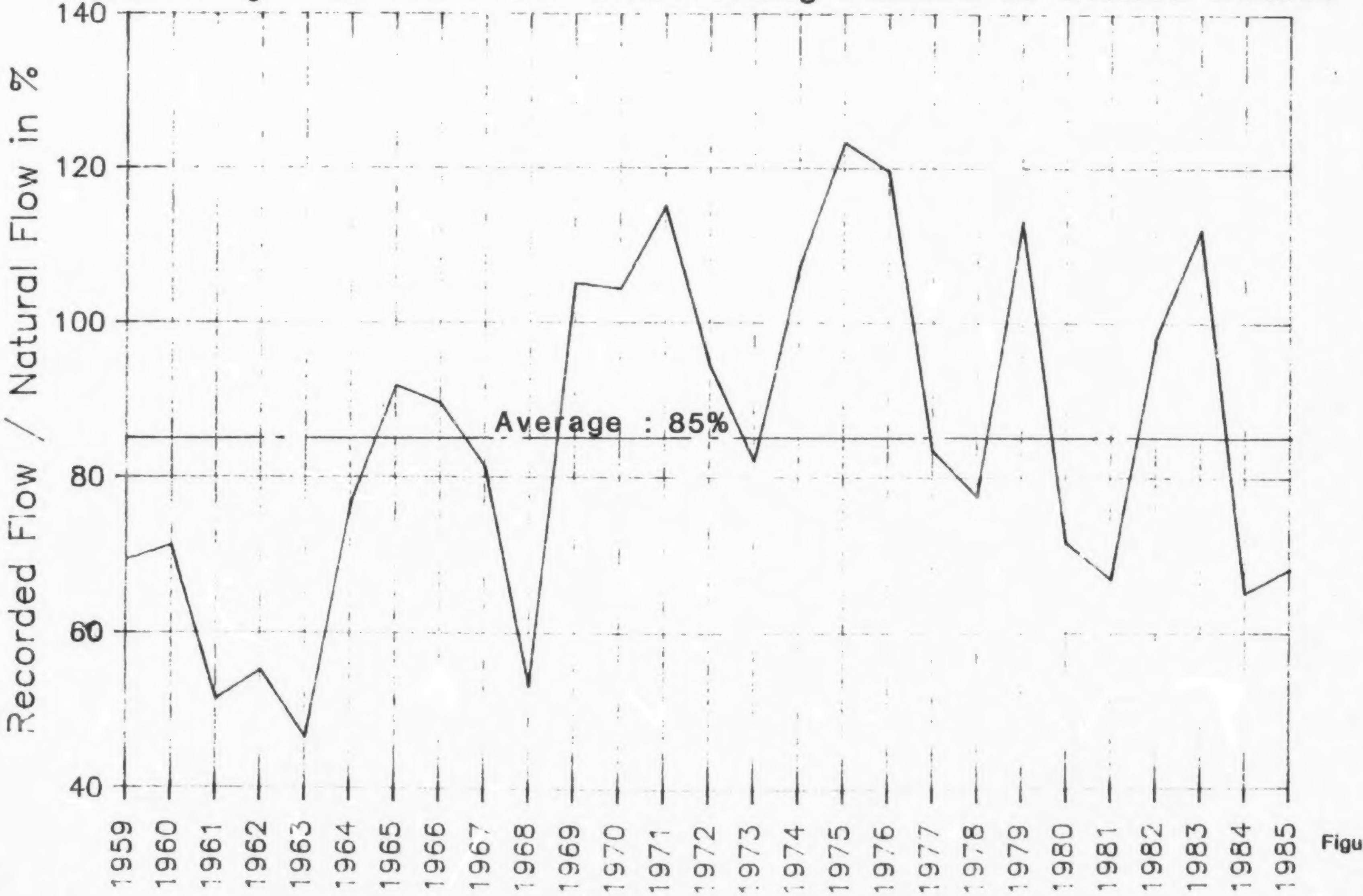


Figure 4.1

The elevation plots (Chapter 3 and Appendix B) for the four scenarios analyzed, show that Rafferty elevations will be quite sensitive to the amount of new consumptive use that develops. The elevations will also be sensitive to how water is shared between Saskatchewan and North Dakota.

At the full level of development of 2,000 ha of irrigation supplied with water from Rafferty Reservoir, the reservoir would experience a drop in elevation over the May to September period of between 0.2 m to 1.0 m with the average decrease being about 0.6 m. The variation would be a function of the amount of summer precipitation and evaporation.

Figure 4.2 shows the frequency that Rafferty Reservoir could be expected to exceed various elevations for each scenario. The results shown on these plots are summarized in Table 4.1.

Table 4.2 is provided to allow a further assessment of how the reservoir characteristics (storage, length, area) would vary as a function of depth. By using Tables 4.1 and 4.2 together, an estimate can be made of how frequently characteristics other than elevation would vary in each scenario. For example, at the full level of irrigation development and 50 percent apportionment (scenario 2), Rafferty will be less than 2 m below FSL 40 percent of the time. Using Table 4.2, it could be concluded that 40 percent of the time the volume of water in storage will be at least 84 percent of maximum, the reservoir length will be at least 90 percent of maximum and the surface area will be at least 92 percent of maximum.

Table 4.1

RAFFERTY RESERVOIR

FREQUENCY-ELEVATION RELATIONSHIP

Depth Below FSL = (m)*	Scenario Percent of Time Exceeding Specified Depth			
	1	2	3	4
0.5	34	14	39	27
1.0	48	23	52	37
2.0	65	40	65	53
3.0	71	56	74	65
4.0	77	64	81	70
5.0	82	71	85	76
6.0	84	75	89	80
7.0	88	79	91	83
8.0	94	84	94	90

* FSL = 550.5 m

Table 4.2

RAFFERTY RESERVOIR

PHYSICAL CHARACTERISTICS

Depth Below FSL	Storage (dam^3)	Area (ha)	Length (km)
0.5	416000	4710	57
1.0	392000	4590	56
2.0	348000	4360	54
3.0	305000	4130	52.5
4.0	265000	3900	49
5.0	227000	3680	48.5
6.0	191000	3470	47.5
7.0	158000	3270	46.5
8.0	126000	3070	45

*FSL = 550.5 m

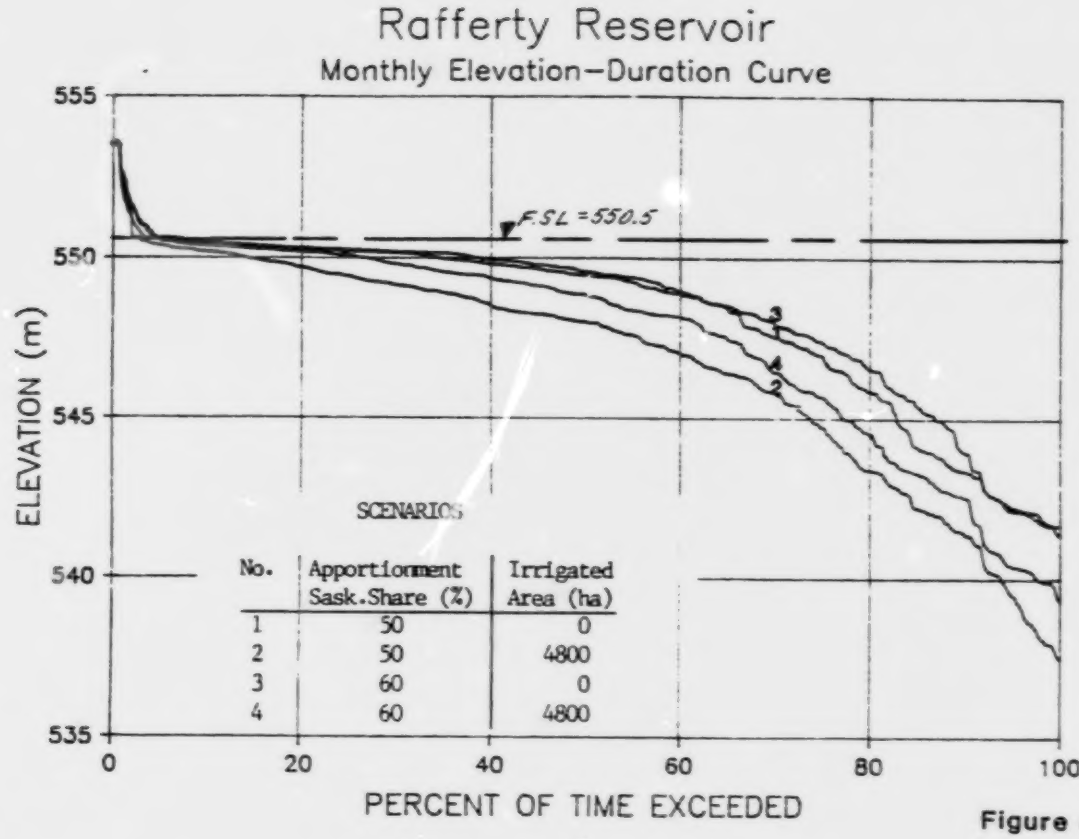


Figure 4.2

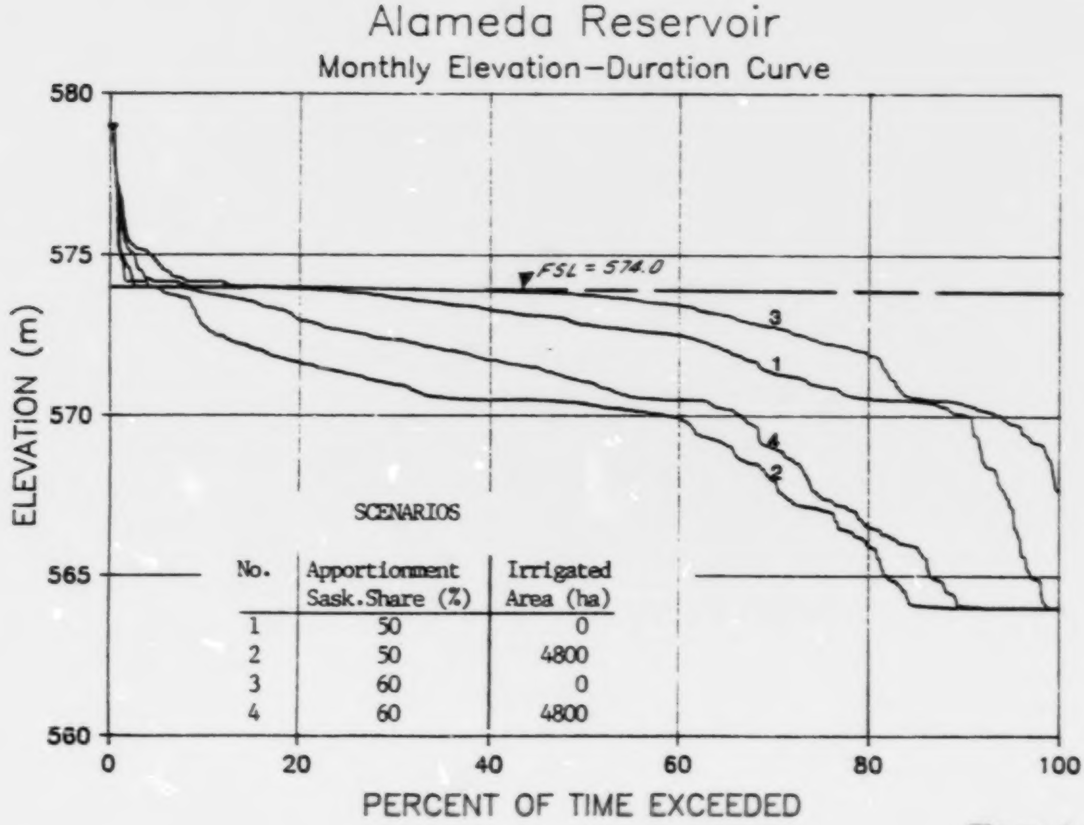


Figure 4.3

4.2.2.2 Alameda Reservoir

The surface water elevation of Alameda Reservoir will be affected both by how water is shared between Saskatchewan and North Dakota and by how much water use is eventually developed from the reservoir supply. Generally, at the full potential irrigation development level of 2,800 ha served from Alameda, the drawdown over the May to September period will range from 1.0 to 2.0 m with the average being about 1.5 m. Over the long term at full irrigation development the reservoir will experience wide fluctuations between its highest and lowest elevations. Figure 4.3 shows the percent of time specified elevations on Alameda Reservoir will be exceeded for each scenario. These results are summarized in Table 4.3.

Table 4.4 is provided to allow an estimate to be made of how other reservoir parameters (area, storage, length) will vary in each scenario.

A comparison of results for scenarios 2 and 4, which assume the same amount of irrigation but have different apportionment assumptions, shows that the water level of Alameda will be fairly dependent on how water is shared. If the sharing corresponds to the arrangements that have been tentatively negotiated between Saskatchewan and North Dakota, then the expected frequency of being at certain elevations will probably fall somewhere between the result shown for scenarios 2 and 4 at the full level of irrigation development.

For the same level of irrigation development the reservoir will be less than 3.0 m below FSL 51 percent of the time with a 40 percent apportionment, as compared to 29 percent of the time with a 50 percent apportionment.

Table 4.3

ALAMEDA RESERVOIR

FREQUENCY-ELEVATION RELATIONSHIP

Depth Below FSL = (m)*	Scenario Percent of Time Exceeding Specified Level			
	1	2	3	4
0.5	35	8	58	15
1.0	48	9	66	20
2.0	65	16	79	36
3.0	74	29	83	51
4.0	91	59	94	67
5.0	92	66	98	70
6.0	94	70	99	74
7.0	95	76	100	79
8.0	96	80	100	84

* FSL = 574.0 m

Table 4.4

ALAMEDA RESERVOIR

PHYSICAL CHARACTERISTICS

Depth Below FSL = (m)*	Storage (dam^3)	Area (ha)	Length (km)
0.5	90,000	1270	24
1.0	84,000	1200	23.3
2.0	72,700	1070	23.0
3.0	62,600	950	21.8
4.0	53,700	840	20.5
5.0	45,800	740	19.2
6.0	38,800	650	17.8
7.0	32,700	570	15.4
8 0	27,400	500	13.0

* FSL - 574.0 m

4.2.3 Channel Flows

4.2.3.1 General

Because of the proposed reservoir storage, the magnitude and pattern of flow in the channels below the reservoirs will be altered. To demonstrate these potential changes, a comparison is made between the flow-duration in the months of April and August for pre-project and post-project conditions at three locations. These locations are the Souris River below Long Creek, Moose Mountain Creek below Alameda Reservoir and Souris River at the International Border.

The April flow-duration curves demonstrate the changes in the frequency of flow magnitude during the high flow spring runoff period, while the August flow duration curves demonstrate the changes during the late summer low flow period.

4.2.3.2 Souris River Below Long Creek

With Rafferty Reservoir and the Boundary to Rafferty diversion channel in place, flow on the Souris River below Long Creek will be controlled in most years. Most of the water that would normally spill from Boundary Reservoir into the Souris River under pre-project conditions, will be diverted to Rafferty Reservoir. Thus, the flow on the Souris River below Long Creek will be dependent on releases from Rafferty which in turn will depend on downstream water demand and how much water will be required to make up the annual apportionment balance. Except for flood conditions, the bulk of releases to the Souris River will be most dependent on the amount of lowland irrigation that develops on the Souris River between Rafferty and Moose Mountain Creek. The lowland irrigation below Moose Mountain Creek will be served from Alameda Reservoir.

To accommodate lowland irrigation development, a series of low level weirs in the Souris River from Rafferty to the International Border will be required to facilitate pumping from the Souris River to the land under irrigation. If the full 3,200 ha of irrigable land was developed approximately 12 weirs would be required.

Figures 4.4 to 4.5 show April and August flow duration curves for all four scenarios.

A comparison of pre-project and post-project flows for April shows that flow during April will be significantly reduced when the project is in place. Although conditions in April are similar for all the scenarios, the average April flow will be largest when full irrigation development takes place and Saskatchewan must pass 50 percent of the annual natural flow. At the full level of irrigation development at Alameda and 50 percent apportionment (scenario 2), releases will occasionally have to be made from Rafferty to make up the apportionment balance. Releases for apportionment will likely be made first from Alameda to the extent that water is available. Although these releases for apportionment could be made later in the year, some of the requirement should be made up in April when channel losses would likely be significantly less than during the summer or fall.

During the summer months, under post-project conditions, flows will likely be enhanced over pre-project conditions. If no new irrigation development takes place as portrayed in scenarios 1 and 3, then the summer flows under post-project conditions will likely be similar to those under pre-project conditions. However, if lowland irrigation develops and is supplied water from Rafferty Reservoir, then the summer flows will be significantly larger under post-project conditions. At the full irrigation development level the summer flows will be up to ten times larger under post-project conditions. Flows greater than 0.5 m^3/s would be experienced approximately 50 percent of the time under post-project conditions compared to ten percent of the time under pre-project conditions.

It is also noted that although water use for the Shand thermal plant was accounted for, releases from Rafferty to meet those demands are not reflected in the flow duration curves. If water is released into the

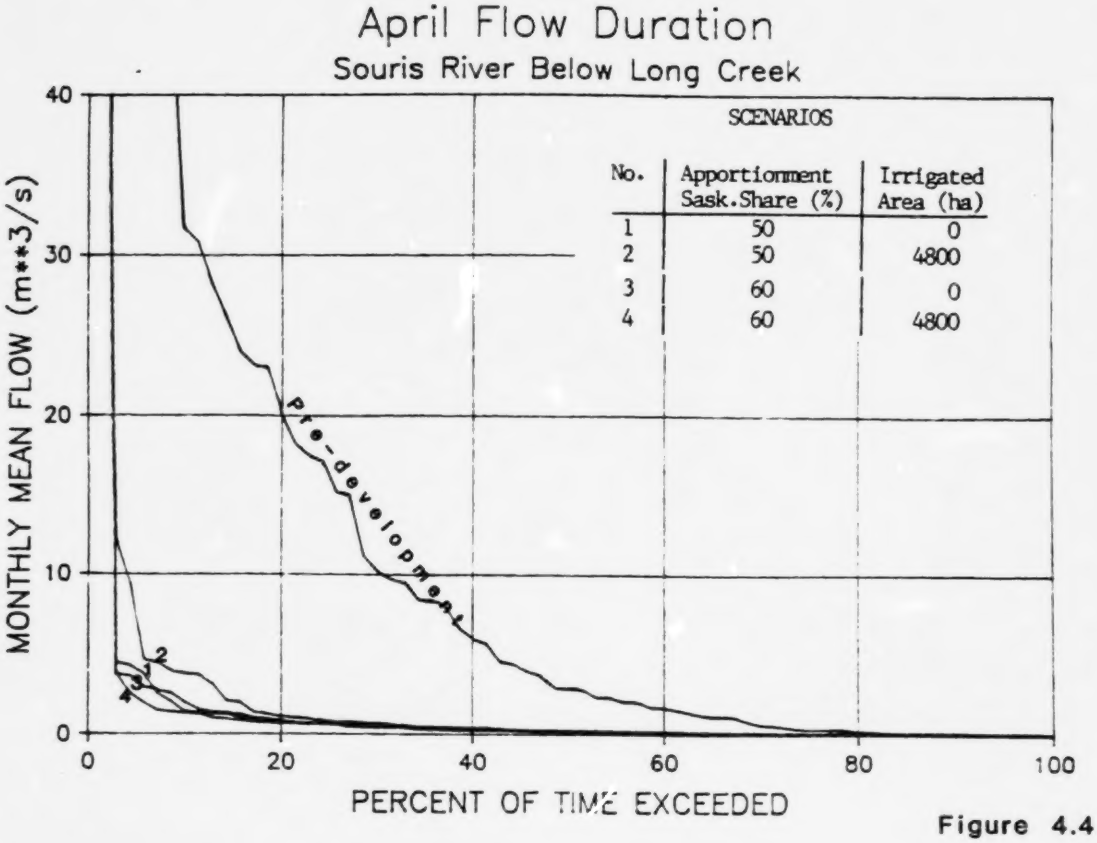


Figure 4.4

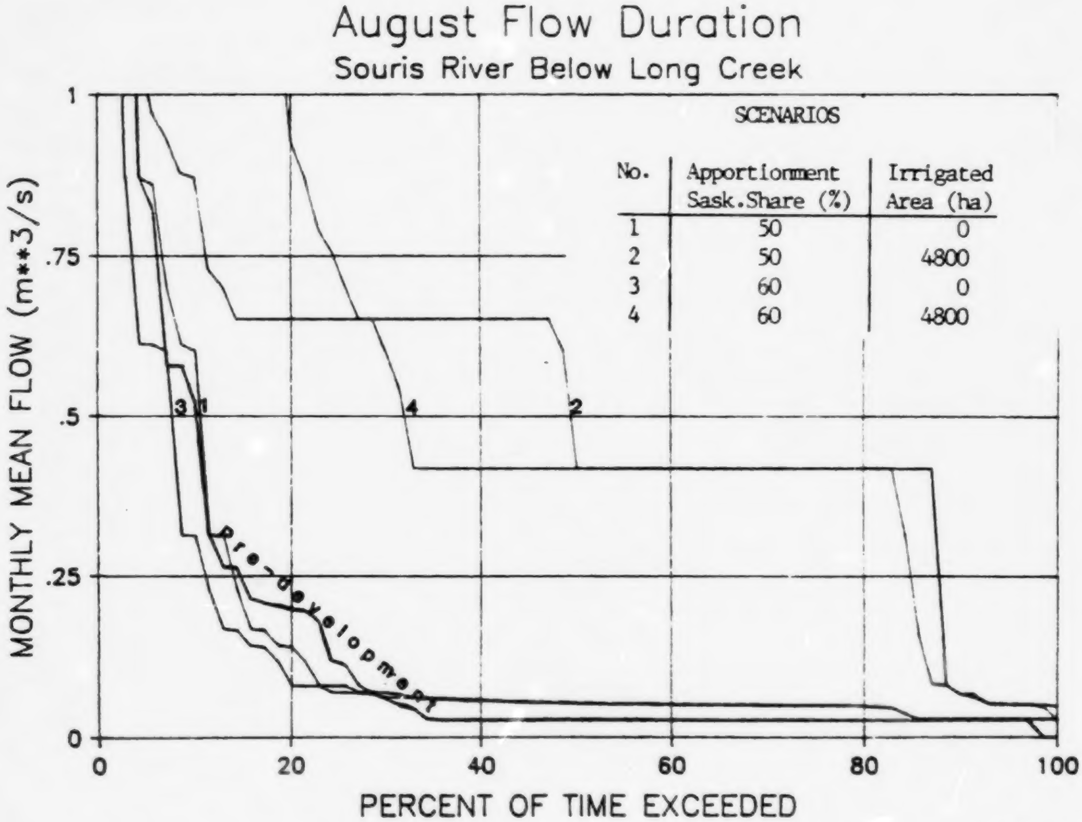


Figure 4.5

channel to meet these demands rather than pumped through a pipeline to the plant, the flows would be augmented in the reach of the river from Rafferty to the Shand plant. The magnitude of these releases is shown in Figure 3.4.

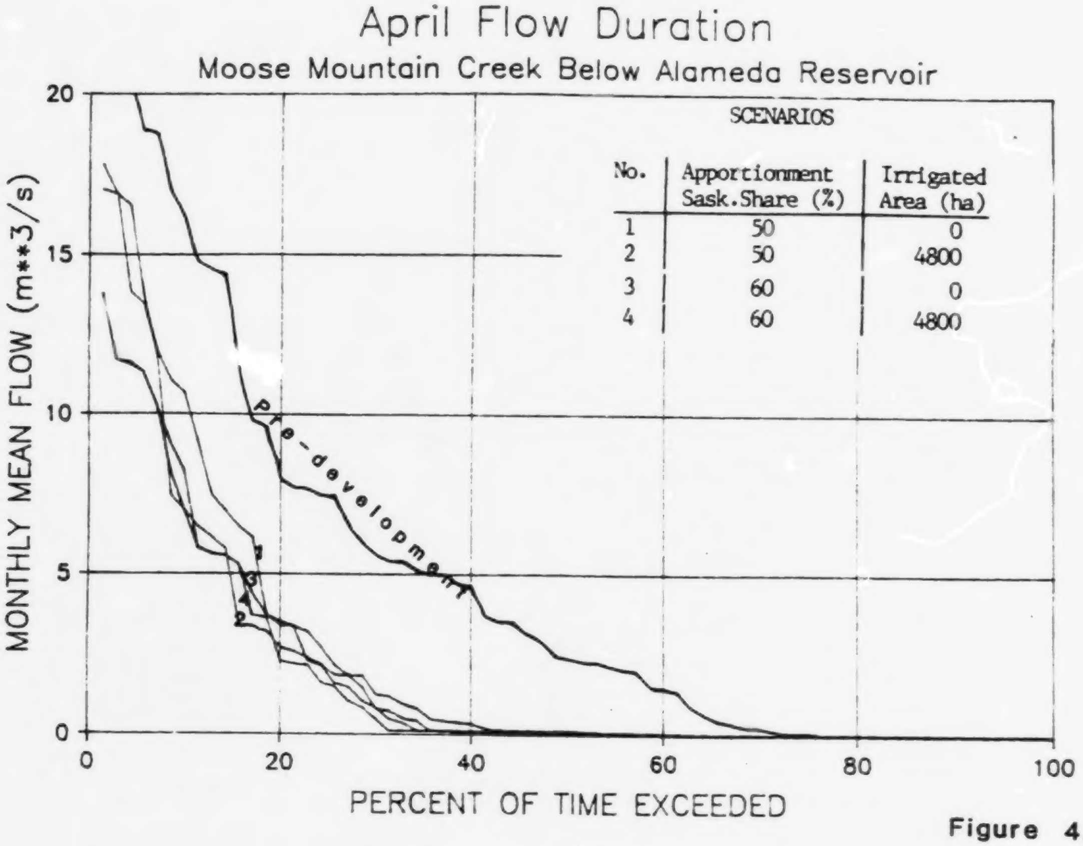
4.2.3.3 Moose Mountain Creek Below Alameda Reservoir

Releases from Alameda Reservoir will be made primarily to meet the requirements of apportionment between Saskatchewan and North Dakota. Consequently, the flow distribution throughout the year will depend on the schedule for meeting North Dakota's annual entitlement. For modelling purposes, releases to make up North Dakota's entitlement were made in proportion to the inflow to the reservoir. That is, if the agreement was to pass, say, 50 percent of the annual volume of natural flow, then this was simulated in the modelling by trying to pass 50 percent of each month's natural flow.

Figures 4.6 to 4.7 show the expected flow duration for April and August monthly mean flows comparing pre and post-project conditions.

Other releases which were accounted for in the modelling but not shown in these channel flows will be for existing and future use in the reach of Moose Mountain Creek, from Alameda Reservoir to the Souris River. Existing use in this reach, averaged over a three-month period, amounts to less than 0.006 m^3/s.

During April, flows will always be less after Alameda Dam is constructed since the objective will be to store as much of the spring runoff as possible.



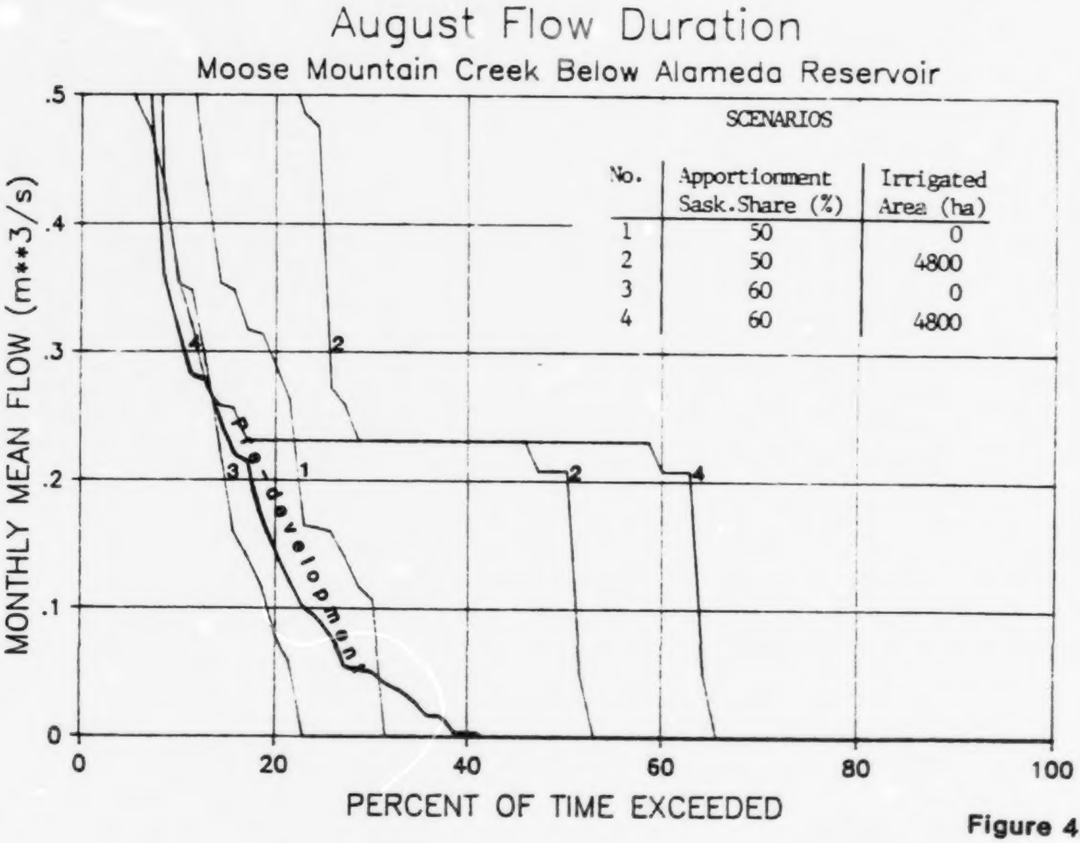
April Flow Duration

Moose Mountain Creek Below Alameda Reservoir

SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure 4.6



August Flow Duration

Moose Mountain Creek Below Alameda Reservoir

SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure 4.7

The amount of irrigation that is developed adjacent to Alameda could affect the frequency of spills from the reservoir and the amount of return flow from an irrigated area and thus, the rate of flow in the channel below the reservoir. The less the amount of irrigation, the greater will be the frequency of spills. The greater the amount of irrigation, the greater will be the potential for increased irrigation return flow which could end up flowing into Moose Mountain Creek below the reservoir. However, the amount of return flow will depend on where the upland irrigation takes place.

Comparing the flow durations for scenarios 1 and 2 shows that during April, higher rates of flow below Alameda could be expected with a greater frequency, if less water was allocated to irrigation from Alameda Reservoir. This would be caused by increased spill.

During the summer, if no lowland irrigation is supplied water from Alameda Reservoir then flows under post-project conditions will be generally similar to those experienced under pre-project conditions, depending upon how the United States apportionment entitlement is made up. If up to 1,200 ha of lowland irrigation is supplied water out of Alameda Reservoir, then summer flows will be significantly increased over pre-project conditions 50 percent of the time. The other 50 percent of the time the flow situation will be similar to pre-project conditions.

4.2.3.4 Souris River at the International Border

Flows at the border will be affected directly by releases from Rafferty and Alameda Reservoirs, spills from Boundary Reservoir, return flow from irrigation, and runoff that occurs from the portion of the basin between the reservoirs and the border. The local uncontrolled flow volume which occurs below the three reservoirs amounts, an average, to about 25 percent of the total natural flow that occurs in the Saskatchewan portion of the basin.

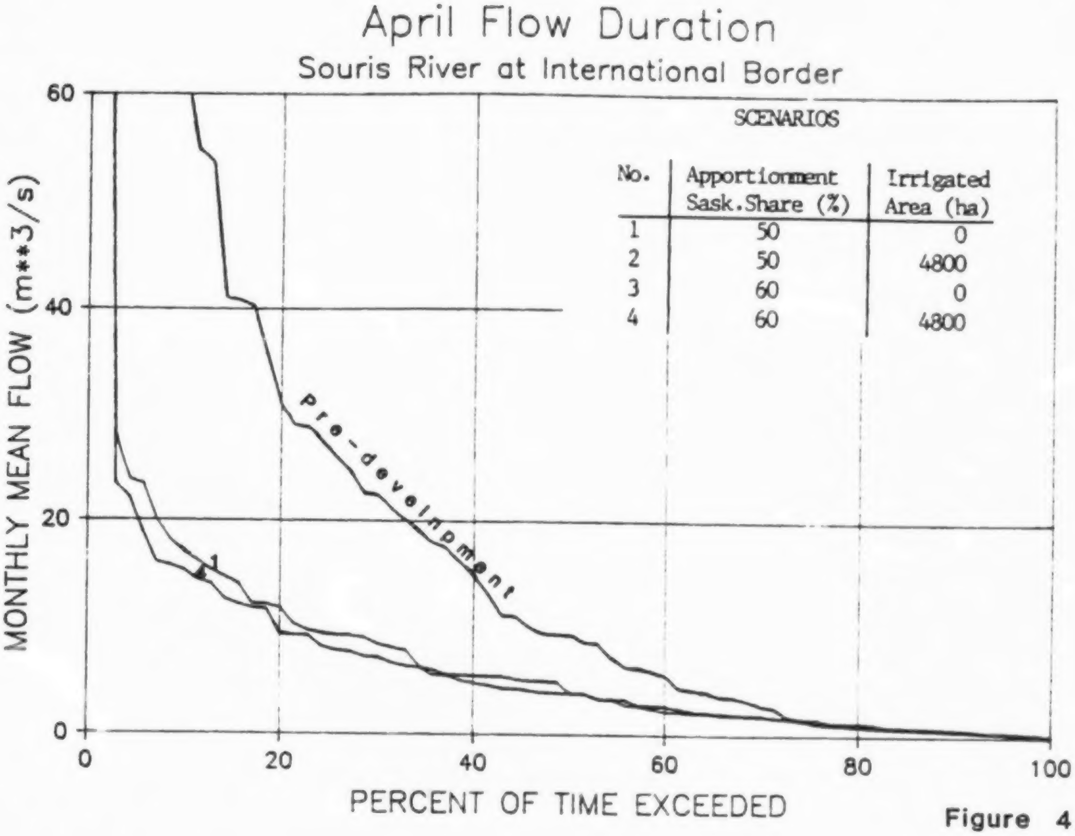


Figure 4.8

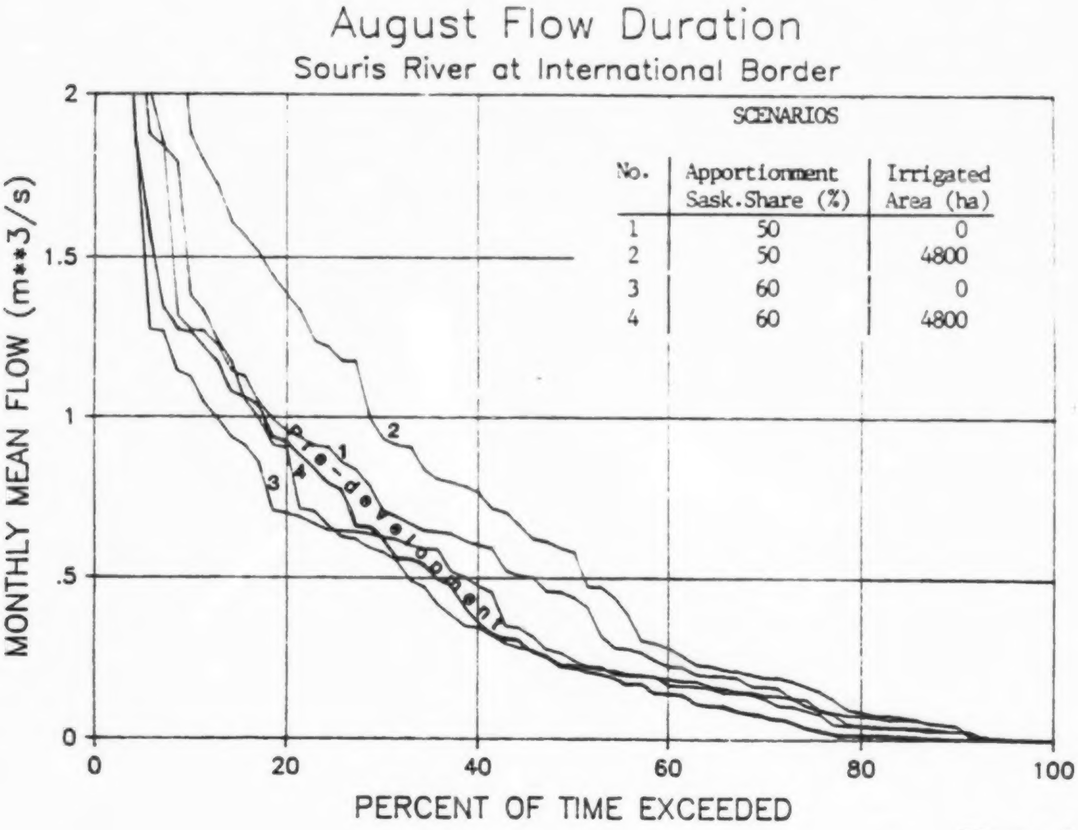


Figure 4.9

Figures 4.8 and 4.9 show the expected flow duration for April and August monthly mean flows comparing pre and post-project conditions.

The plot of the April flow-duration shows that under post-project conditions as in the cases of the other channels, flows of any magnitude will be less frequent than those that would be experienced under pre-project conditions. However, during August, flows will generally be higher more often with the project in place as a result largely of potential return flows from irrigation. The flows representing the project conditions reflect an assumption that 10 percent of the water diverted for irrigation would return to the river as irrigation return flow above the border. The largest increase in August flows will occur under scenario 2 conditions with a 50 percent apportionment. If Saskatchewan was entitled to 60 percent of the water, less would pass the border and the August flow-duration curve depicting post-project flow conditions would be very close to the pre-project flow duration curve.

4.2.3.5 Channel Flow Impact Summary

The discussion on hydrologic impacts to channel flows has attempted to interpret potential impacts based on the results of computer model simulations. The channel flows at any location will be very dependent on the amount and location of lowland irrigation that is developed, and the schedule that Saskatchewan adopts for making releases to meet the United States' annual natural flow entitlement. The schedule of releases to meet apportionment could vary from year to year. Saskatchewan will establish that schedule in consultation with United States' agencies to maximize benefits to Saskatchewan. Considerations might include the timing of releases to correspond with spring runoff and thus to minimize channel losses. Alternatively, there might be value in holding the water over the summer to enhance recreation use on the reservoirs. Although the modelling shows that sometimes late fall releases were made (even into December) to make up apportionment, it is likely that most deficits would be made up before the end of October.

As a general statement, greater irrigation use would cause less frequent spills from the reservoirs. Most irrigation projects generate return flow which will be proportional to the amount diverted for irrigation. Some of the return flow might enter the channel below the dams and augment the flow during the summer period. Experience with other projects in Saskatchewan shows that this return flow volume could amount to between 10 and 20 percent of the total volume diverted for irrigation. For the purposes of this assessment, it was assumed that 10 percent of the water diverted for lowland irrigation would return to the Souris River as irrigation return flows. However, the degree to which irrigation return flow will affect channel flows depends on the location of the irrigation projects and the manner of operation.

It is also noted that although flow conditions for particular months (April and August) were shown, streamflow takes on seasonal characteristics. During the spring (March, April and May) there will be uncontrolled runoff from the spring snowmelt that will contribute to flow in the river channel below the reservoirs. During the summer, the channel flows will be augmented by reservoir releases for apportionment and consumptive uses (irrigation). During the early fall there might be need to make special reservoir releases in some years to make up any deficits to apportionment. During the late fall and winter, channel flow conditions under post-project conditions will be similar to those under pre-project conditions with generally no augmentation by reservoir releases. The large degree of control offered by the project will permit a fair degree of flexibility to maintain predetermined flow conditions in the channels in the spring, summer or fall months (open water season) as long as the water demands can be, including the United States apportionment entitlement.

4.3 FLOOD CONTROL

The proposed Rafferty Reservoir will have approximately 192,900 dam^3 of available flood storage between full supply level of 550.5 metres and maximum flood level of 554.0 metres. This capacity will be available to temporarily store flood flows to effect some measure of downstream flood control. If Rafferty Reservoir is nearly full prior to a flood runoff, some additional storage can be made available, depending on the flood forecast, by releasing water out of Rafferty Reservoir before runoff starts (pre-flood drawdown).

The proposed Alameda Reservoir will have approximately 86,400 dam^3 of available flood storage between full supply level of 574.0 m and maximum flood level of 579.0 m to temporarily store flood flows. Like Rafferty, it too could be drawn down prior to runoff to make additional storage available.

The potential for reducing peak flows comparing pre and post-project conditions is summarized in Table 4.5. This table shows for each flood event, for three locations, the percentage reduction in flood peak that would occur as a result of having Rafferty and Alameda Reservoirs in place. The results show that the greatest percentage reduction for all flood events, as reflected by the conditions at the International Border, would occur in the reach of the Souris River below Moose Mountain Creek.

For all locations the measure of flood reduction deceases as the magnitude of the flood event increases. Downstream of Long Creek flooding (flow in excess of bank capacity) would likely be eliminated for events up to a 1:50. However, for less frequent floods (higher magnitude) than a 1:50 event, flooding could still occur, but at a reduced level with some measure of benefit received for flood events up to and including the 1:500.

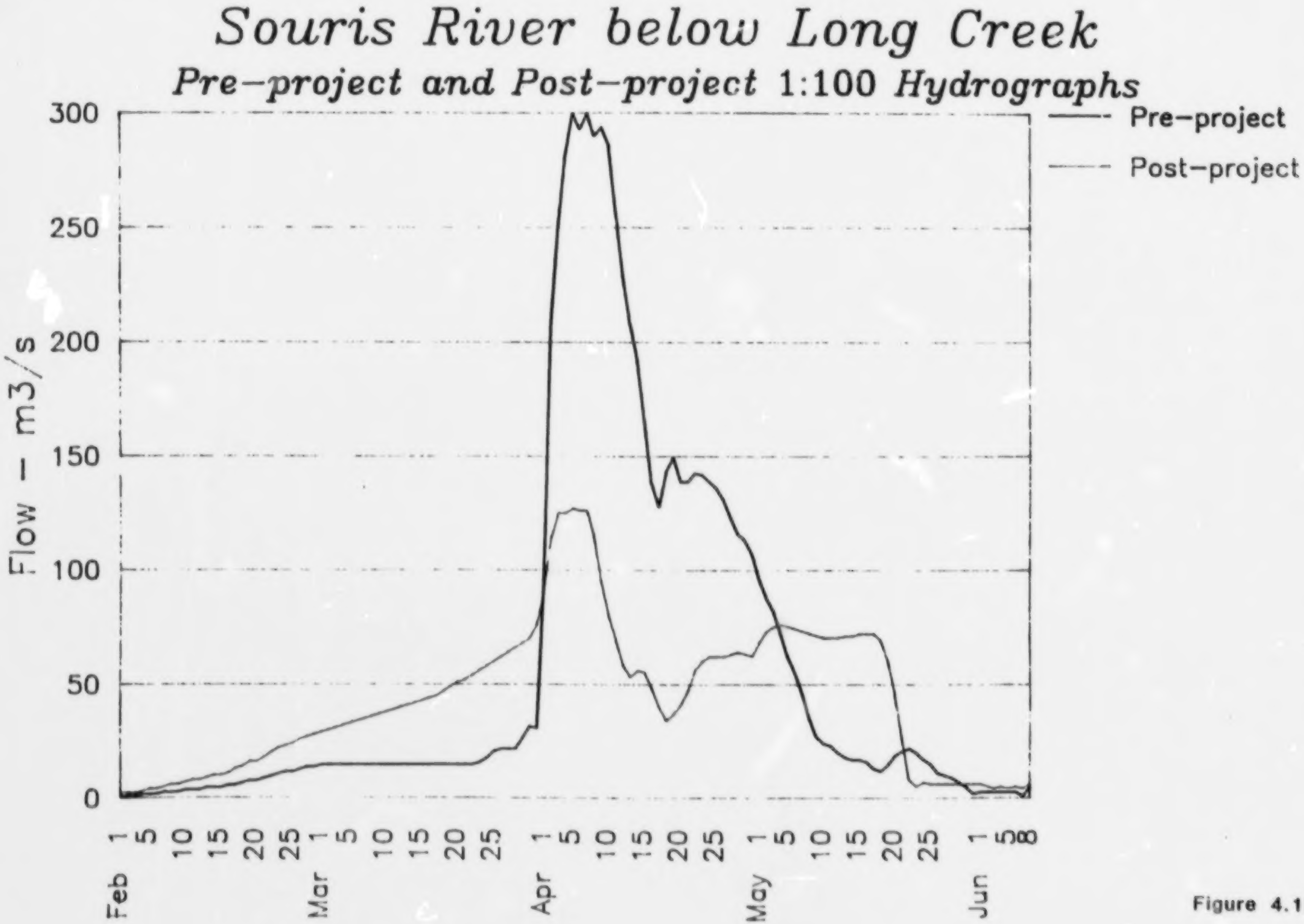
The flooding that occurs on the Souris River below Long Creek occurs mainly as a result of the flow on Long Creek. Since Boundary Reservoir has very little capacity to store flood waters, the reservoir generally fills quickly during a flood and the flow must be spilled. The proposed Boundary to Rafferty diversion channel will reduce this effect by diverting some of the flood water that would normally spill at Boundary into Rafferty Reservoir.

Spill from Boundary Reservoir not only affects the flood conditions downstream of the confluence of Long Creek and the Souris River but also upstream on the Souris River. Because the reach of the Souris River above Long Creek has a very flat channel bottom, water from Long Creek will flow up the Souris River when the water surface elevation in Long Creek at the mouth is greater than the water surface elevation of the Souris River above Long Creek. Consequently, even when Rafferty Dam is in place, water from Long Creek will still back up the Souris River during high flows and the reach of the Souris River between Rafferty Dam and Long Creek will still be subject to occasional flooding. However, the frequency and magnitude of flooding will be significantly reduced.

To show the flow conditions with and without the Rafferty and Alameda project, a detailed assessment was made of the 1:100 flood. Figures 4.10 and 4.11 show the 1:100 flows with and without the project on the Souris River below Long Creek at Estevan and on the Souris River near the International Border at Sherwood.

Throughout the length of the Souris River from Long Creek to the border, the operation of Rafferty and Alameda Reservoirs and the Boundary to Rafferty diversion will reduce the flooding for all events up to and including the 1:500. The greatest impact will be in the reach of the Souris River below Moose Mountain Creek. That reach benefits from both Alameda and Rafferty Reservoirs.

Tables 4.6 and 4.7 provide additional information on the impact of the 1:100 flood. During the 1:100 flood, Rafferty and Alameda Reservoirs would reach their maximum flood level. To minimize the flood potential downstream and to meet the United States requirements of not exceeding 14 m^3/s at the border between June 1st and August 31st, the reservoirs would not likely be down to their full supply levels until October. For flood events up to and including the 1:50, both reservoirs would likely be down to their full supply levels by June 1st.



Souris River below Long Creek

Pre-project and Post-project** 1:100 **Hydrographs

Figure 4.10

Souris River near Sherwood

Pre–project and Post–project 1:100 Hydrographs

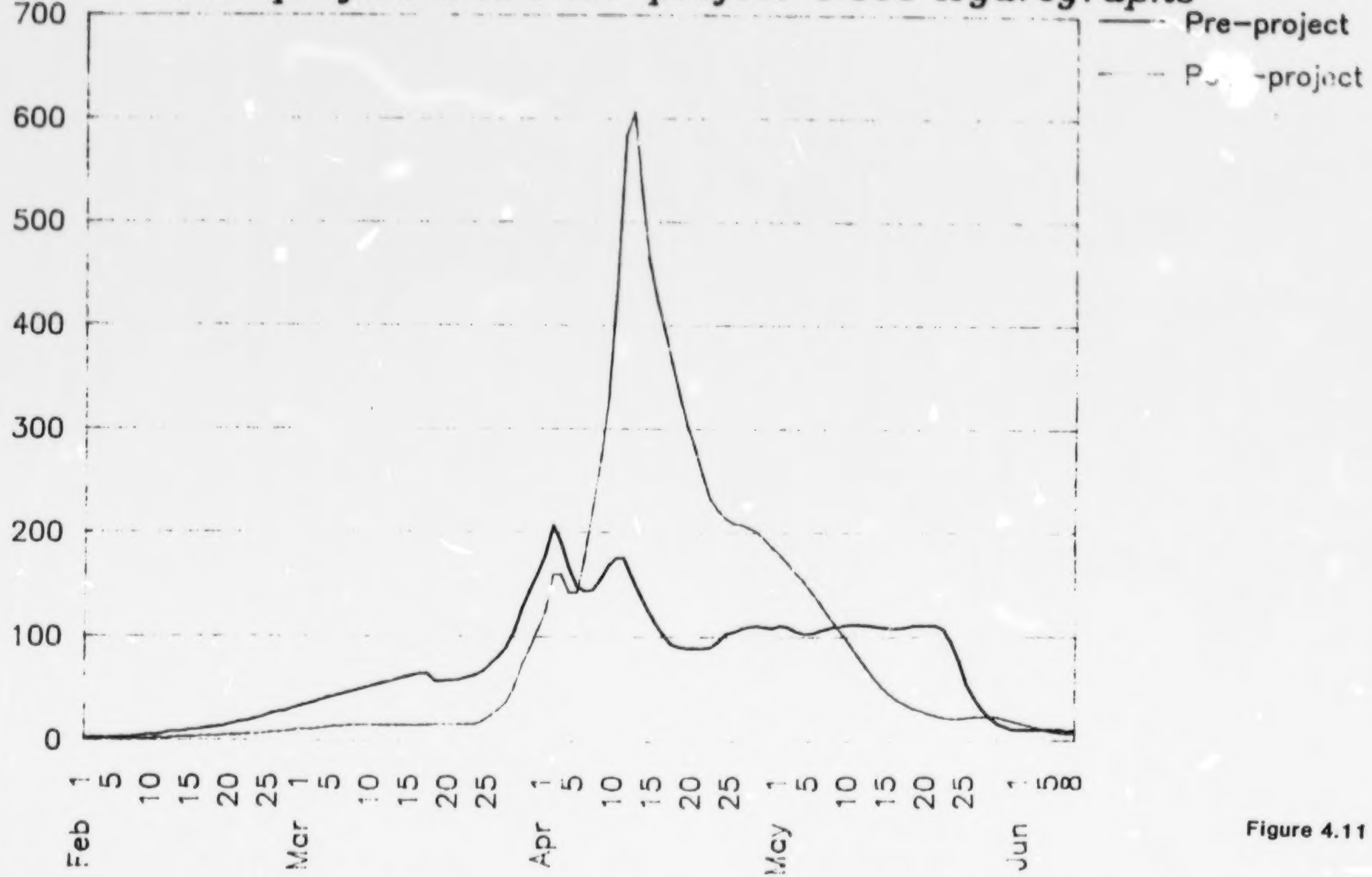


Figure 4.11

In the event of a 1:100 flood, the peak flows at Estevan on the Souris River below Long Creek will be reduced by over 25 percent and the duration of flooding will be cut by over 70 percent. In the lower reaches of the Souris River (below Moose Mountain Creek) flood peaks will be reduced by over 65 percent but the duration of flooding at some locations will be increased from 41 days to 57 days. The bank full capacity in this reach of the Souris River varies from over 200 m^3/s at Oxbow to 90 m^3/s at the border. Consequently, since flows throughout the 57 day duration will be less than 113 m^3/s nearly 70 percent of the time, not all portions of the Souris River below Moose Mountain Creek will experience an increase in duration of flooding.

Table 4.5

FLOOD REDUCTION CAPABILITY

Flood Event	Estevan Project Peak (m^3/s) Pre	Estevan Project Peak (m^3/s) Post	Estevan Percent Reduction	Roche Percee Project Peak (m^3/s) Pre	Roche Percee Project Peak (m^3/s) Post	Roche Percee Percent Reduction	International Border Project Peak (m^3/s) Pre	International Border Project Peak (m^3/s) Post	International Border Percent Reduction
1:50	219	60	72	225	95	58	417	155	62
1:100	300	130	57	318	160	50	607	208	66
1:500	545	394	28	573	445	22	1078	430	60

Table 4.6

1:100 RESERVOIR FLOOD CHARACTERISTICS

	Rafferty	Boundary	Alameda
Maximum Inflow (m^3/s)	226	246	323
Maximum Outflow (m^3/s)	70	130	57
Minimum Elevation (m)	547.4	556.37	565.0
Maximum Elevation (m)	553.5	560.76	579.0
May 31st Elevation (m)	552.7	560.76	576.9
Time to Return to FSL* (days)	120	-	80

*After May 31st.

Table 4.7

1:100 FLOOD DURATIONS

(DAYS)

	Estevan[1)]	Oxbow to Sherwood[2)]
Pre-Project	32	41
Post Project	9	57

1) Based on number of days above bank full capacity of 85 m^3/s.
2) Based on number of days above bank full capacity of 90 m^3/s at Glen Ewen.

4.4 CONCLUSIONS

Based on the analyses that have been done, some general conclusions can be made about the potential hydrologic impact of the project. However, it must be kept in mind that the analyses provided through application of the computer models are totally contingent on the input data and the assumptions. The best way to utilize the information is to examine the changes that take place in the hydrologic regime as a result of changing assumptions; hence, the need to compare results between scenarios rather than concentrate on the absolute results provided by a single scenario.

4.4.1. The Rafferty and Alameda Reservoirs and the Boundary to Rafferty diversion channel would allow Saskatchewan to store and use its share of annual natural flow of the Souris River in most years.

4.4.2. The water stored in Rafferty and Alameda Reservoirs would provide adequate supply to maintain existing consumptive water uses downstream of the reservoirs, maintain the water requirements of the proposed Shand electric generating station, irrigate up to 4,800 ha of land not currently under irrigation and provide two bodies of water suitable for water based recreation.

The conclusion that the supply to Shand will be viable is based on the results of the water supply modelling. For the historic record of natural flow used in the modelling, there were years when the natural inflow to Rafferty Reservoir was insufficient to meet the Shand generating station water supply requirements. In those years, the short fall was made up from water stored in Rafferty. Because the historic flow record is the best information that we have and includes the effects of two extreme droughts in the 1930's and early 1960's, the modelling results have to be considered as a credible basis upon which to expect the supply to Shand to remain viable and that carry over water will be available in low flow years. If, in the future, drought occurs with a greater frequency than evidenced from the historic records, the water supply requirements for Shand might not be able to be met.

However, because of its large storage capacity, Rafferty would be drawn down gradually over a succession of low flow years providing sufficient lead time to enact a contingency plan such as water rationing to lessen the rate of depletion or development of groundwater supplies for Shand.

4.4.3. After construction of each reservoir there would be a filling period for each reservoir to reach full supply level. This amount of time would be dependent upon both the characteristics of annual runoff and the amount of water use that develops. There would be approximately a 50 percent probability of Rafferty Reservoir achieving 55 percent of its maximum full supply level storage within five years. For Alameda Reservoir there would be approximately a 50 percent probability of achieving 70 percent of its maximum full supply level storage in five years.

4.4.4. Historical patterns of runoff indicate that, in the future, the reservoirs will experience successive years of continual increase in water level and successive years of continual decrease, interspaced by years of stable levels. A drought like the 1930's would reduce both reservoirs to levels close to their minimum supply levels.

4.4.5. The proposed manner for operating the reservoirs would provide flood control benefits in Saskatchewan. The 1:100 flood on the Souris River below Long Creek would be reduced by over 50 percent. Floods of greater frequency (smaller floods) would be reduced even more.

4.4.6. The flow regime that would be established in the Souris River below the reservoirs would be highly dependent on the operation of the reservoirs. In general, these reservoirs would be operated to store water and make specific releases to meet downstream demands including North Dakota's annual share of the natural flow. Flows in the spring would generally be less than those experienced under existing conditions. Flows during the summer would likely be greater than those under existing conditions if a demand for water is created through development of lowland irrigation.

REFERENCES

Reference No.

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2 Souris River Basin Study Report; Souris River Basin Study Board, June, 1978.

3 Report on Engineering Studies at Alameda Dam, Moose Mountain Creek; Canada Department of Regional Economic Expansion, PFRA, Engineering Service, Saskatchewan Regional Division, May, 1976.

4 Souris River Flood Study; Saskatchewan Power Corporation (Fennell, Cochrane, Lavalin), April, 1985.

5 Rafferty Reservoir Multi-use Feasibility Study, Phase 1 Report; Saskatchewan Power Corporation (Fennell, Cochrane, Lavalin), September, 1983.

6 Rafferty Reservoir Study, Phase 2; Saskatchewan Power Corporation (Fennell, Cochrane, Lavalin), January, 1985.

7 Rafferty and Alameda Reservoirs, Conceptual Evaluation of Irrigation and Recreation Costs and Benefits; Saskatchewan Water Corporation (Water Resource Consultants Ltd.), December, 1985.

APPENDIX B

Water Supply Modelling Results

List of Figures

B.1 Rafferty Reservoir Elevations - Scenario 1

B.2 Rafferty Reservoir Elevations - Scenario 2

B.3 Rafferty Reservoir Elevations - Scenario 3

B.4 Alameda Reservoir Elevations - Scenario 1

B.5 Alameda Reservoir Elevations - Scenario 2

B.6 Alameda Reservoir Elevations - Scenario 3

B.7 Monthly Mean Flow Hydrograph
Souris River Below Long Creek- Scenario 1

B.8 Monthly Mean Flow Hydrograph
Souris River Below Long Creek- Scenario 2

B.9 Monthly Mean Flow Hydrograph
Souris River Below Long Creek- Scenario 3

B.10 Monthly Mean Flow Hydrograph
Moose Mountain Creek Below Alameda Reservoir - Scenario 1

B.11 Monthly Mean Flow Hydrograph
Moose Mountain Creek Below Alameda Reservoir - Scenario 2

B.12 Monthly Mean Flow Hydrograph
Moose Mountain Creek Below Alameda Reservoir - Scenario 3

B.13 Monthly Mean Flow Hydrograph
Souris River at International Border - Scenario 1

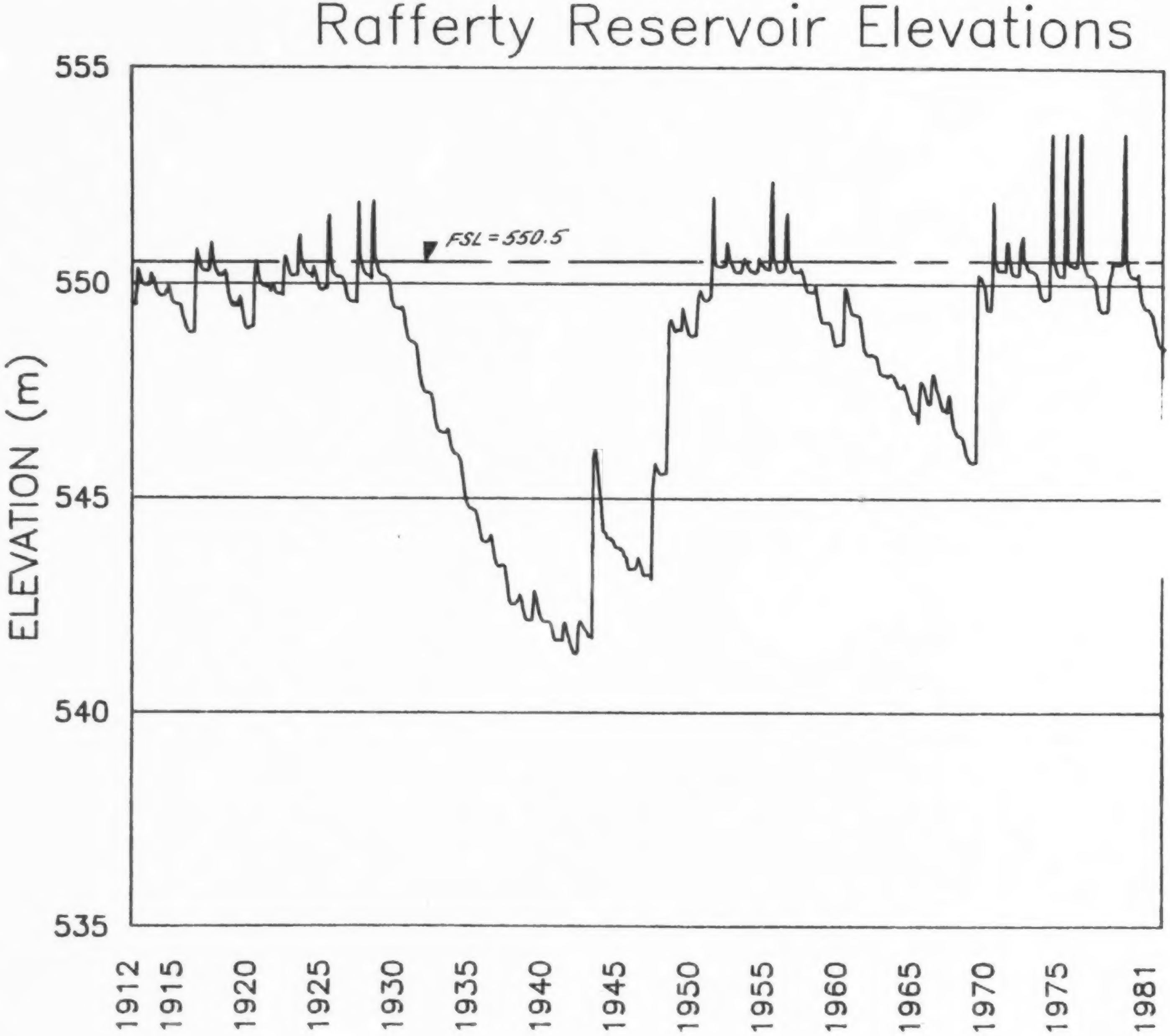
B.14 Monthly Mean Flow Hydrograph
Souris River at International Border - Scenario 2

B.15 Monthly Mean Flow Hydrograph
Souris River at International Border - Scenario 3

B.16 Annual Volume
Souris River Below Long Creek - Scenario 2

B.17 Annual Volume
Moose Mountain Creek below Alameda Reservoir - Scenario 2

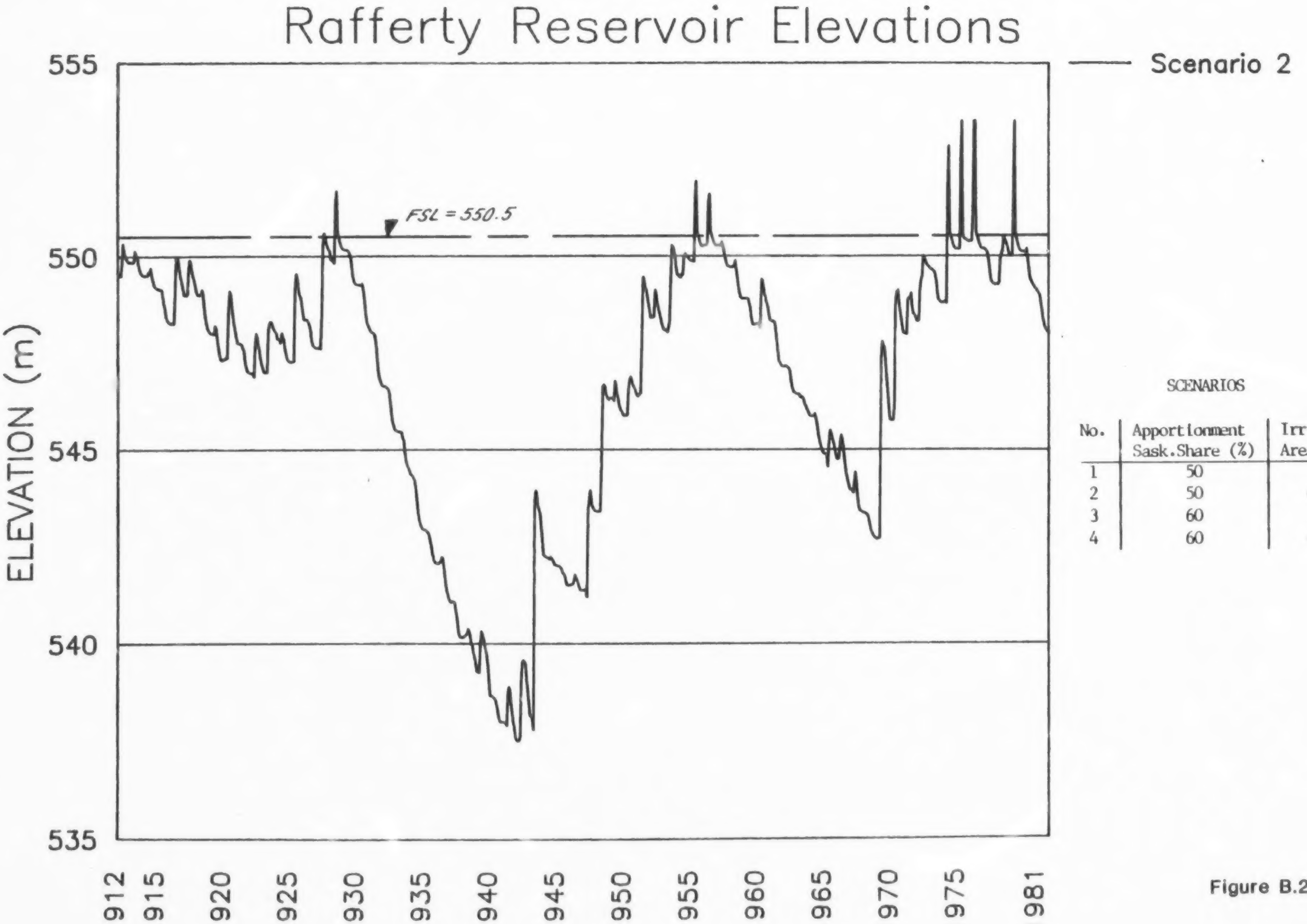
B.18 Annual Volume
Souris River at International Border - Scenario 2



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

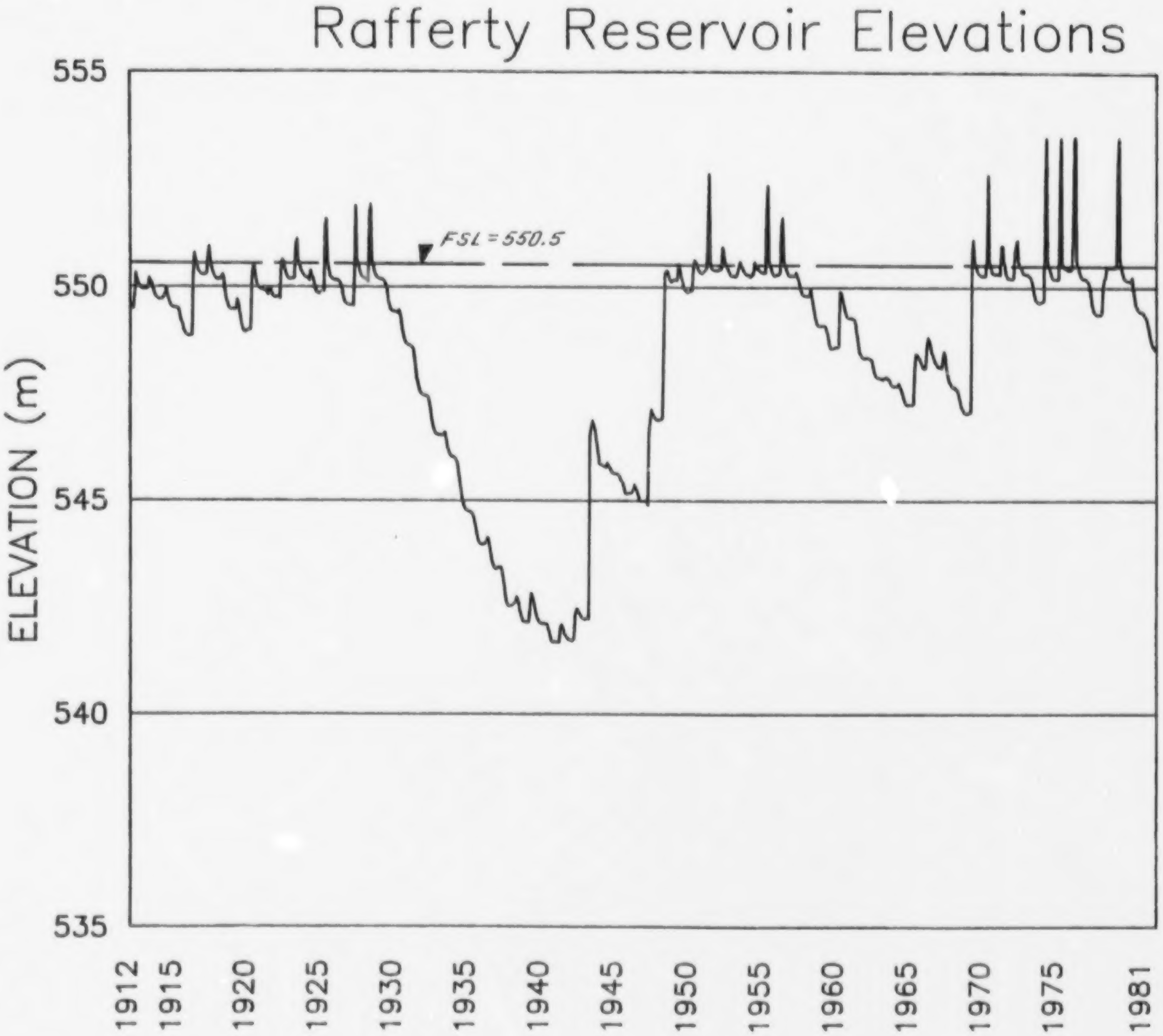
Figure B.1



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.2

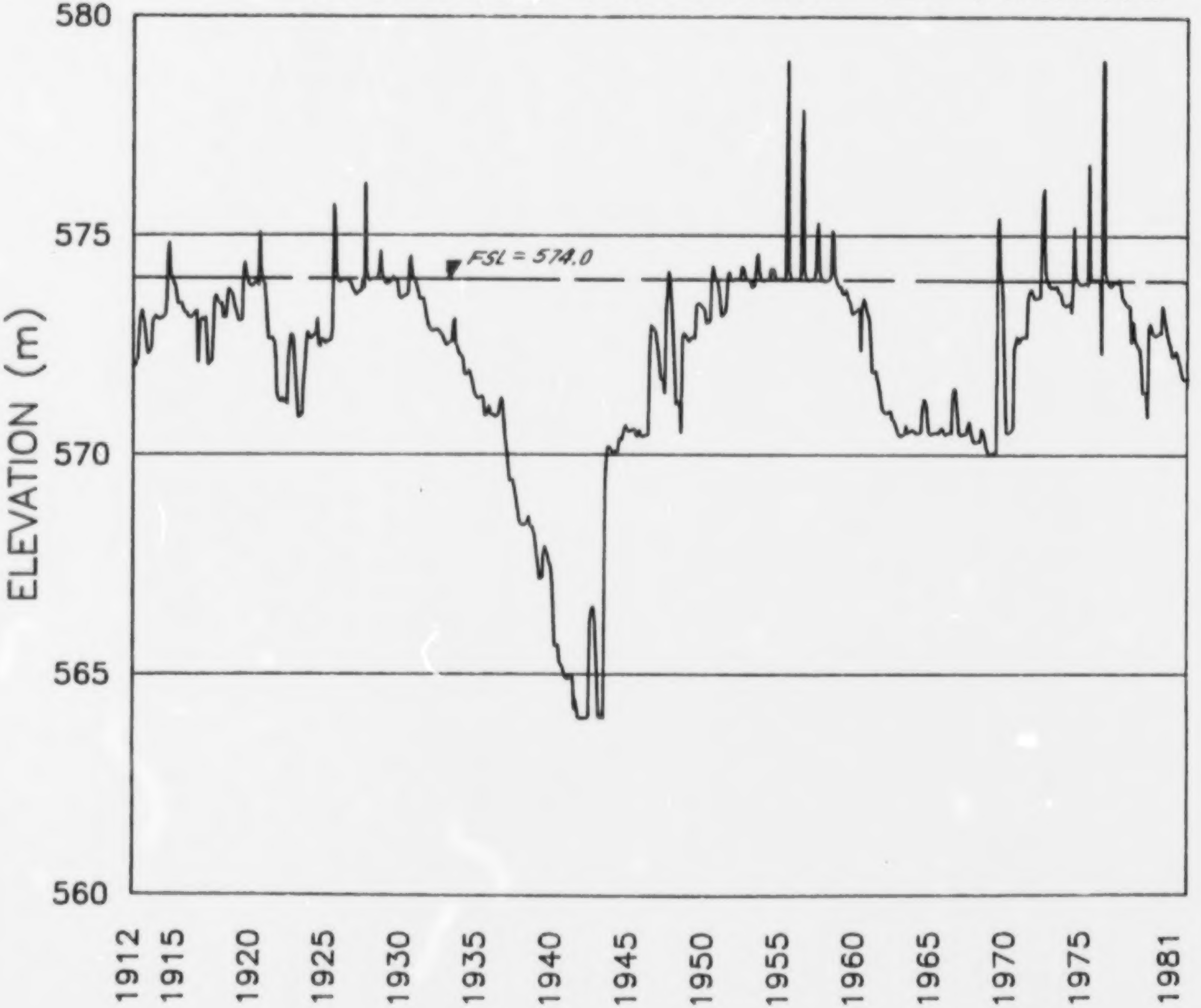


SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.3

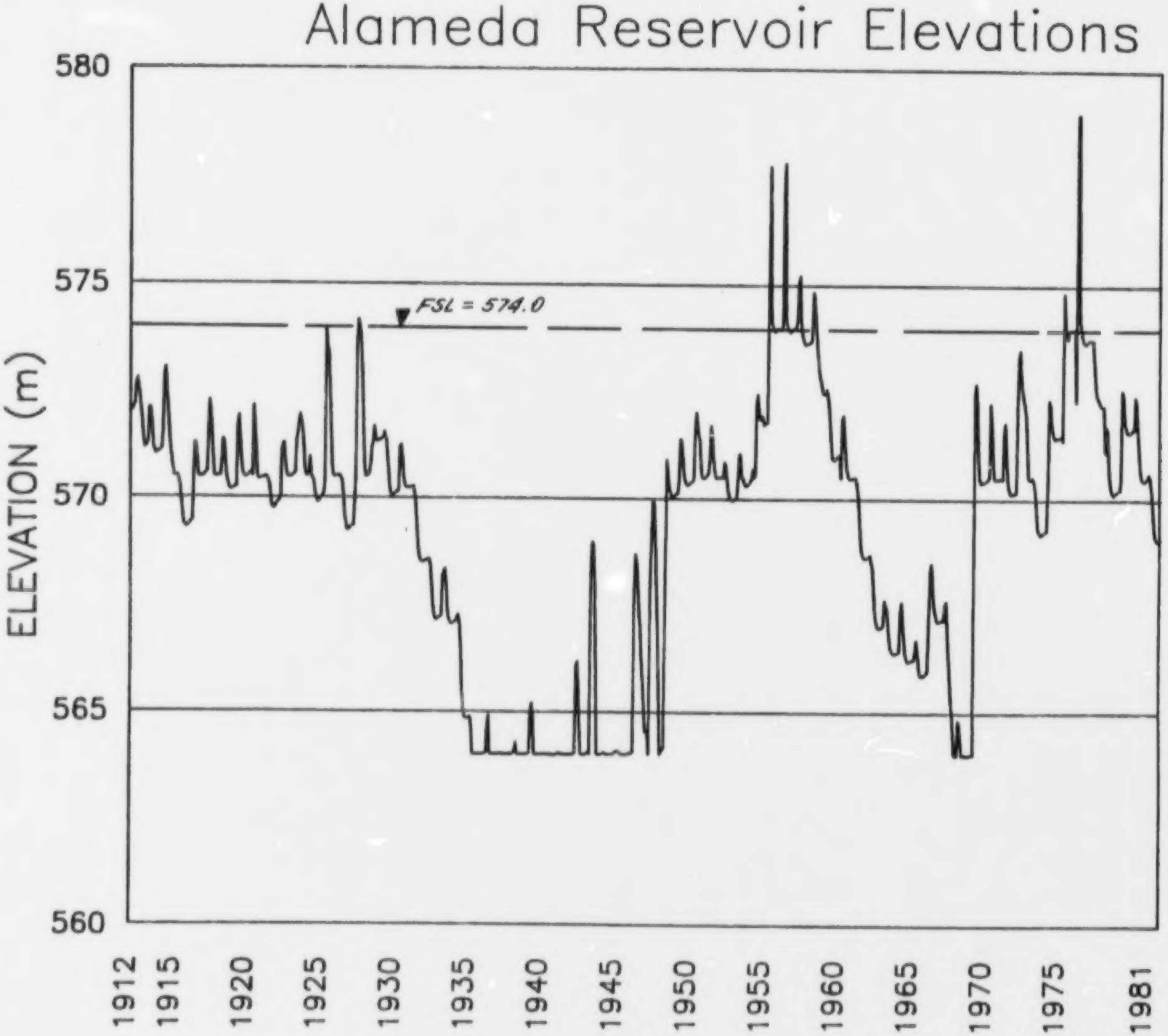
Alameda Reservoir Elevations



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

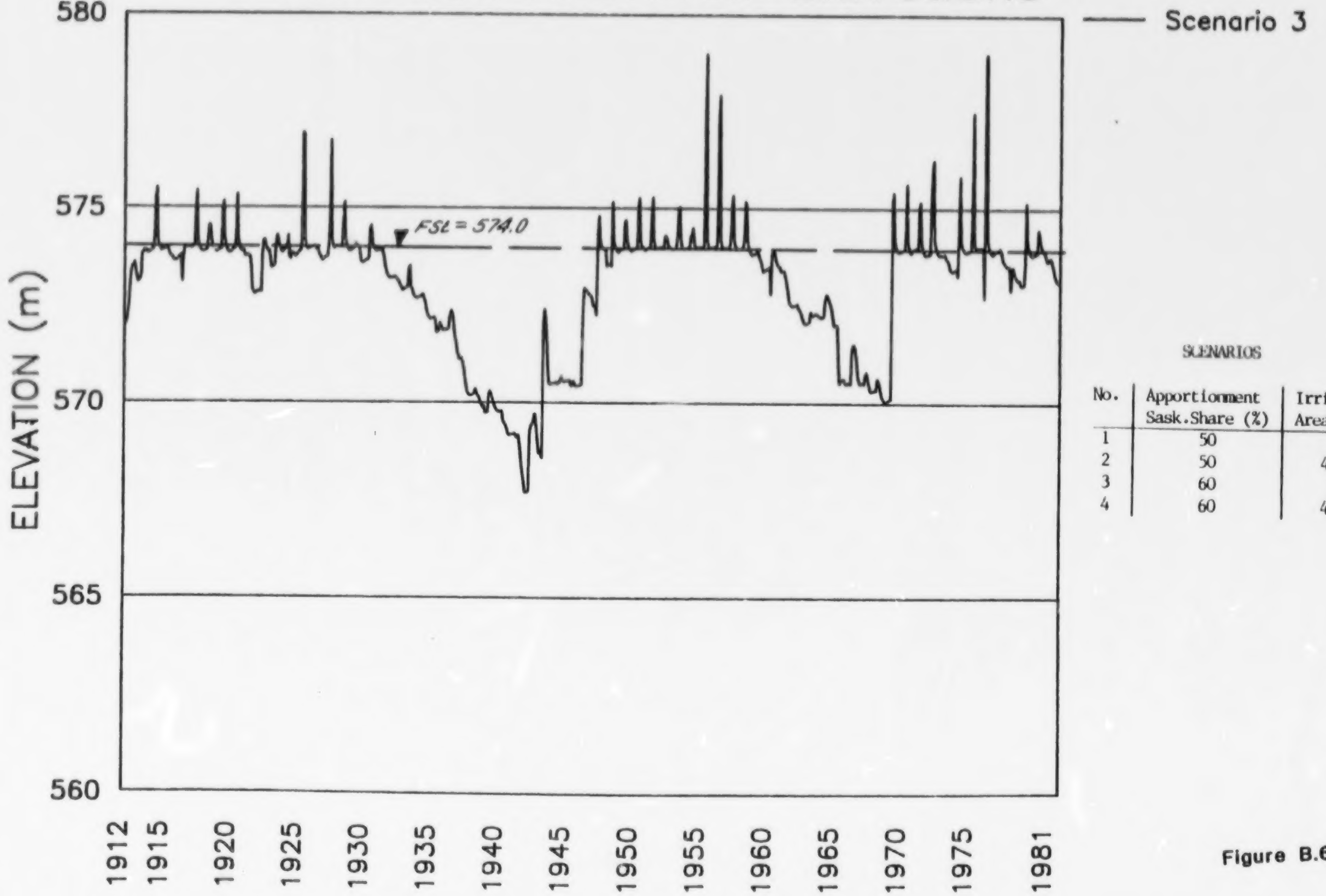
Figure B.4



SCENARIOS

No.	Apportionment Sask. Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B5

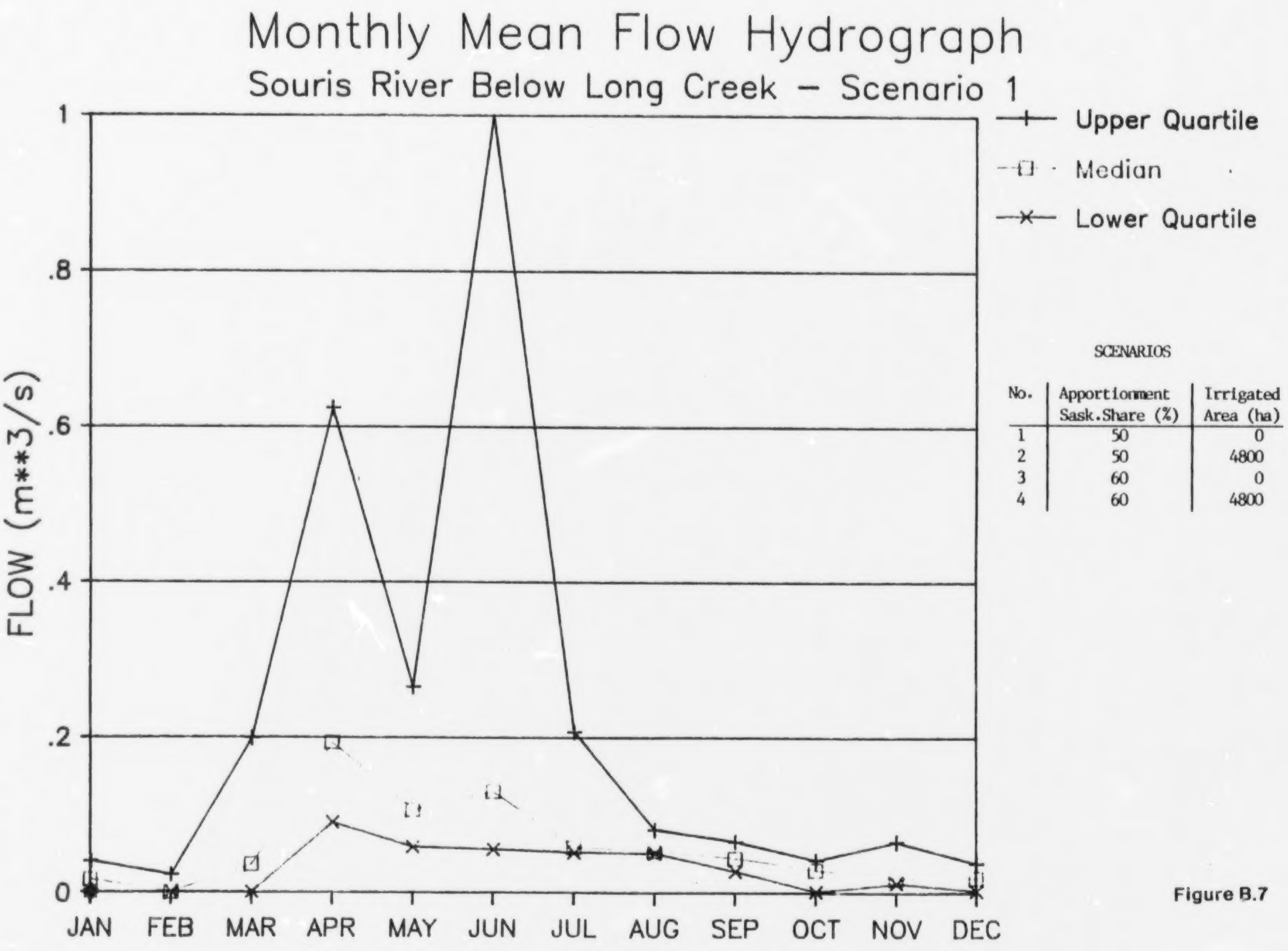


Alameda Reservoir Elevations

SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.6



Monthly Mean Flow Hydrograph

Souris River Below Long Creek – Scenario 1

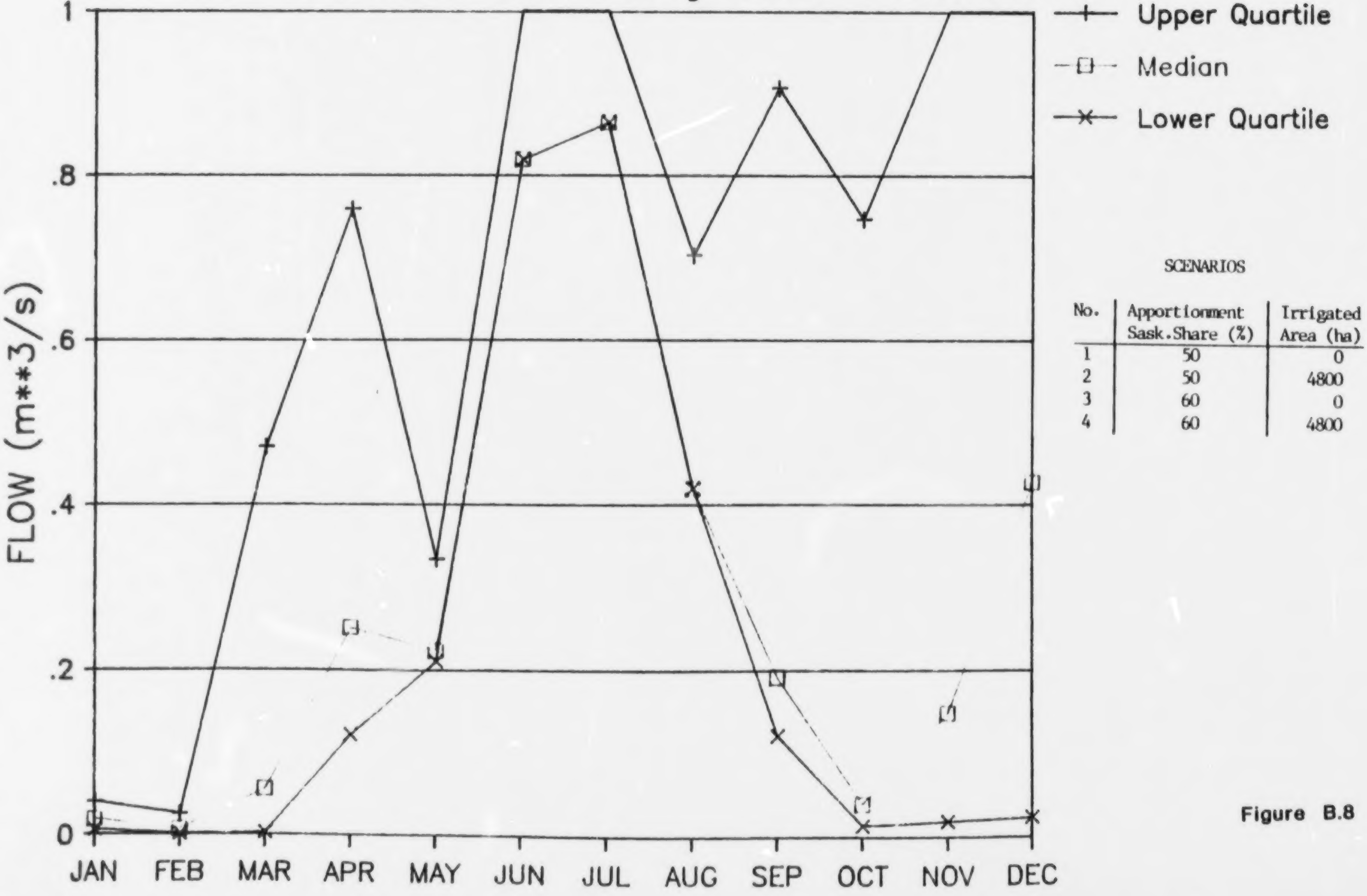
SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.7

Monthly Mean Flow Hydrograph

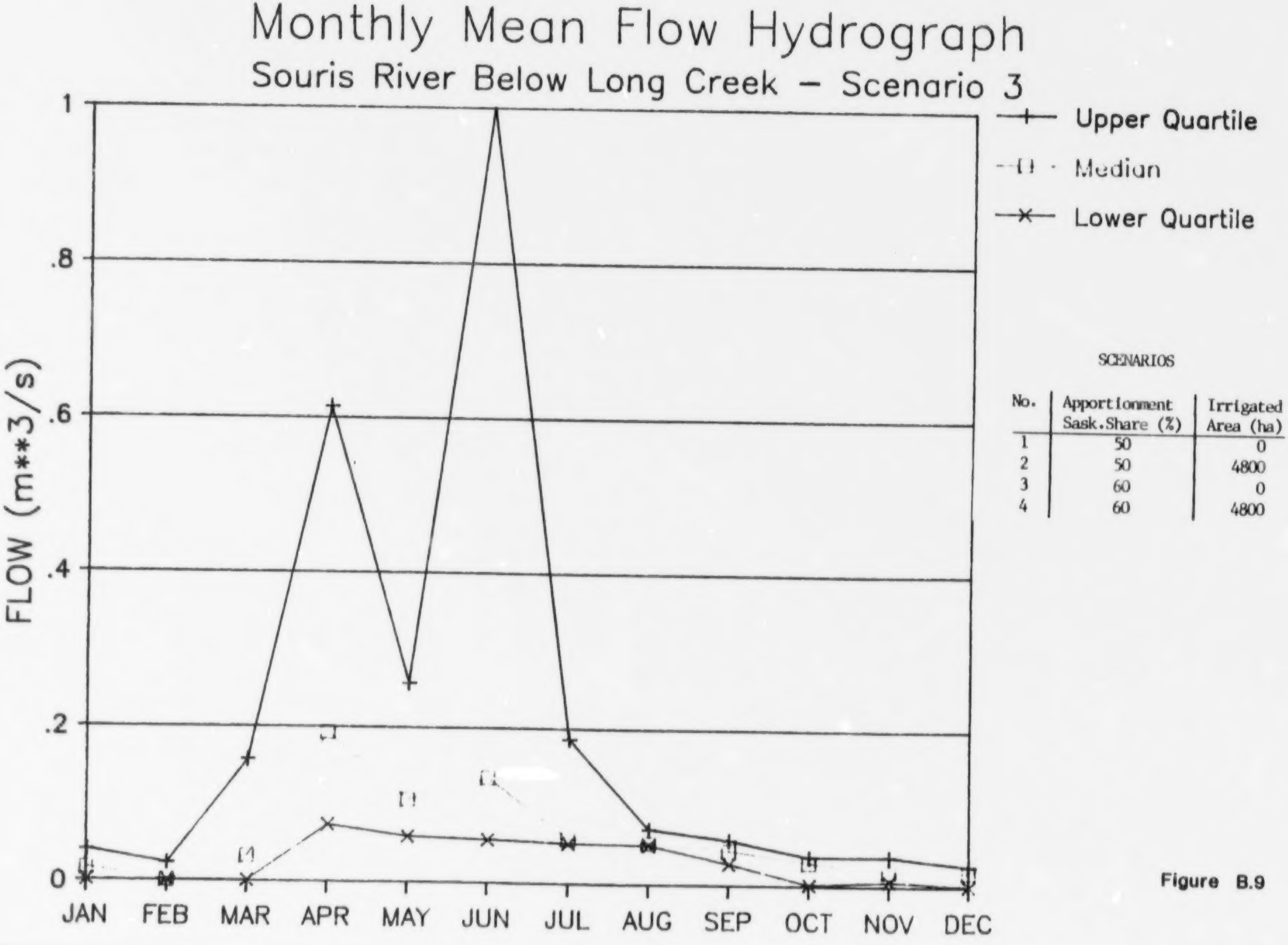
Souris River Below Long Creek – Scenario 2



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

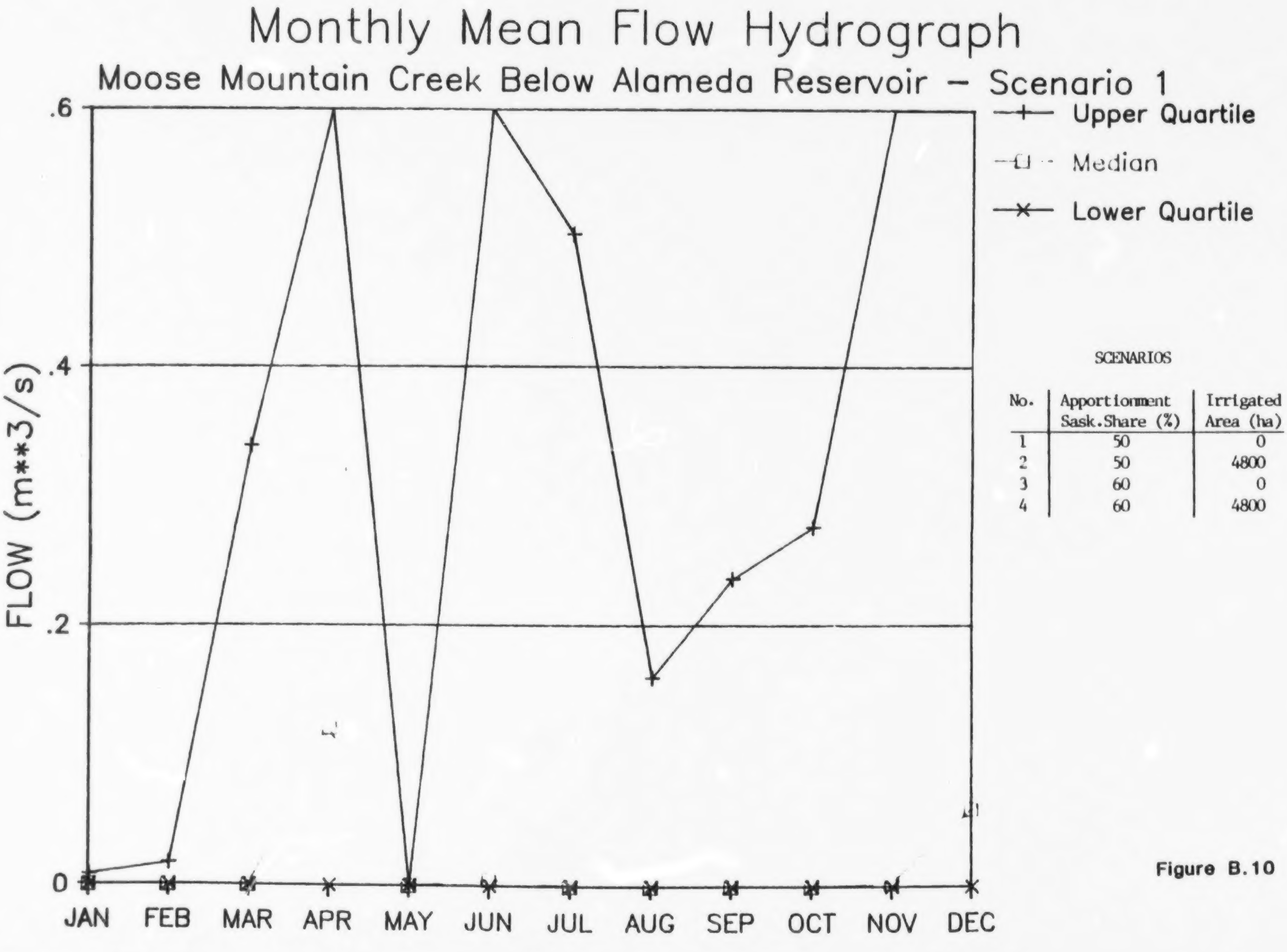
Figure B.8



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

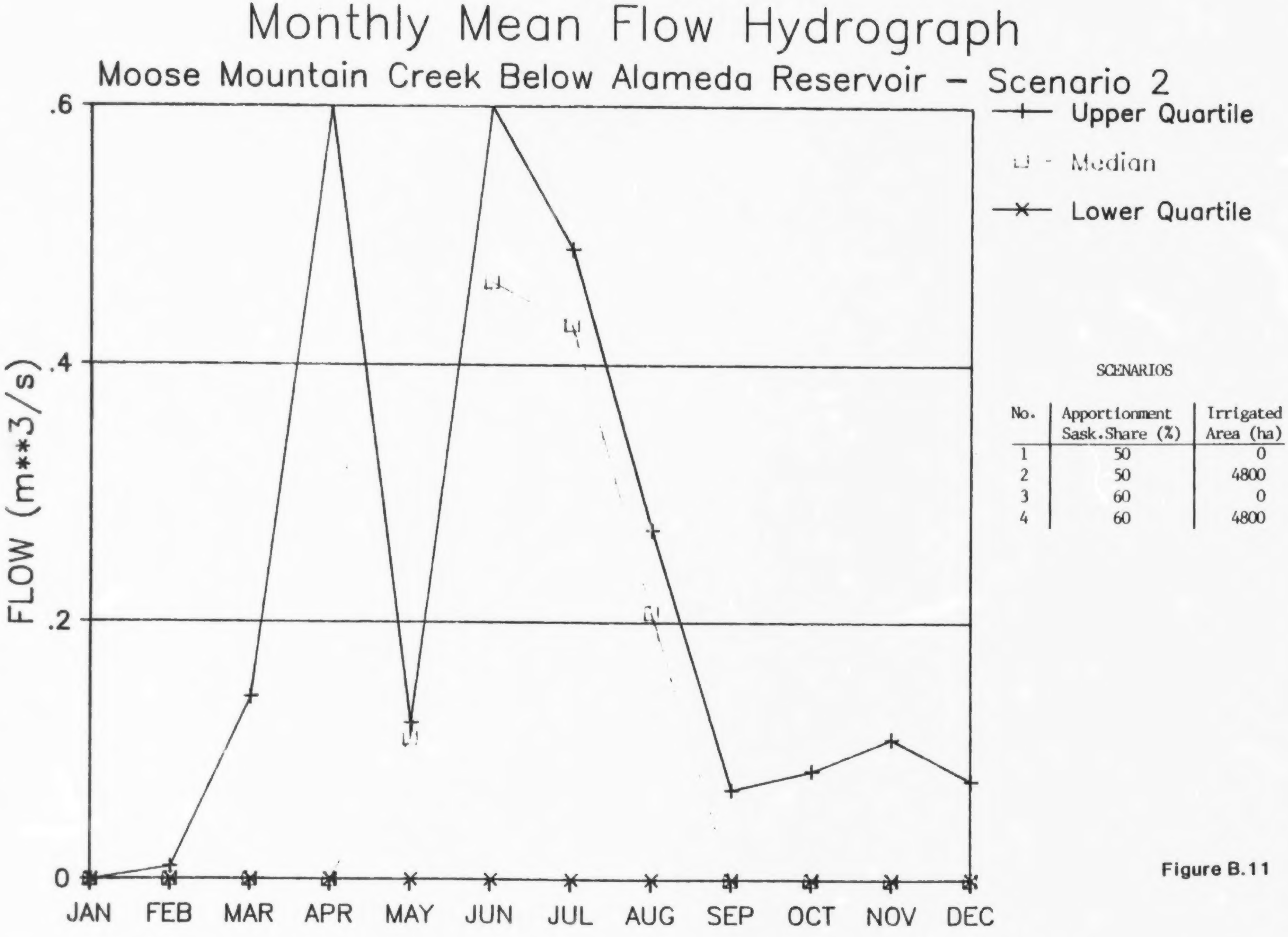
Figure B.9



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.10


Monthly Mean Flow Hydrograph

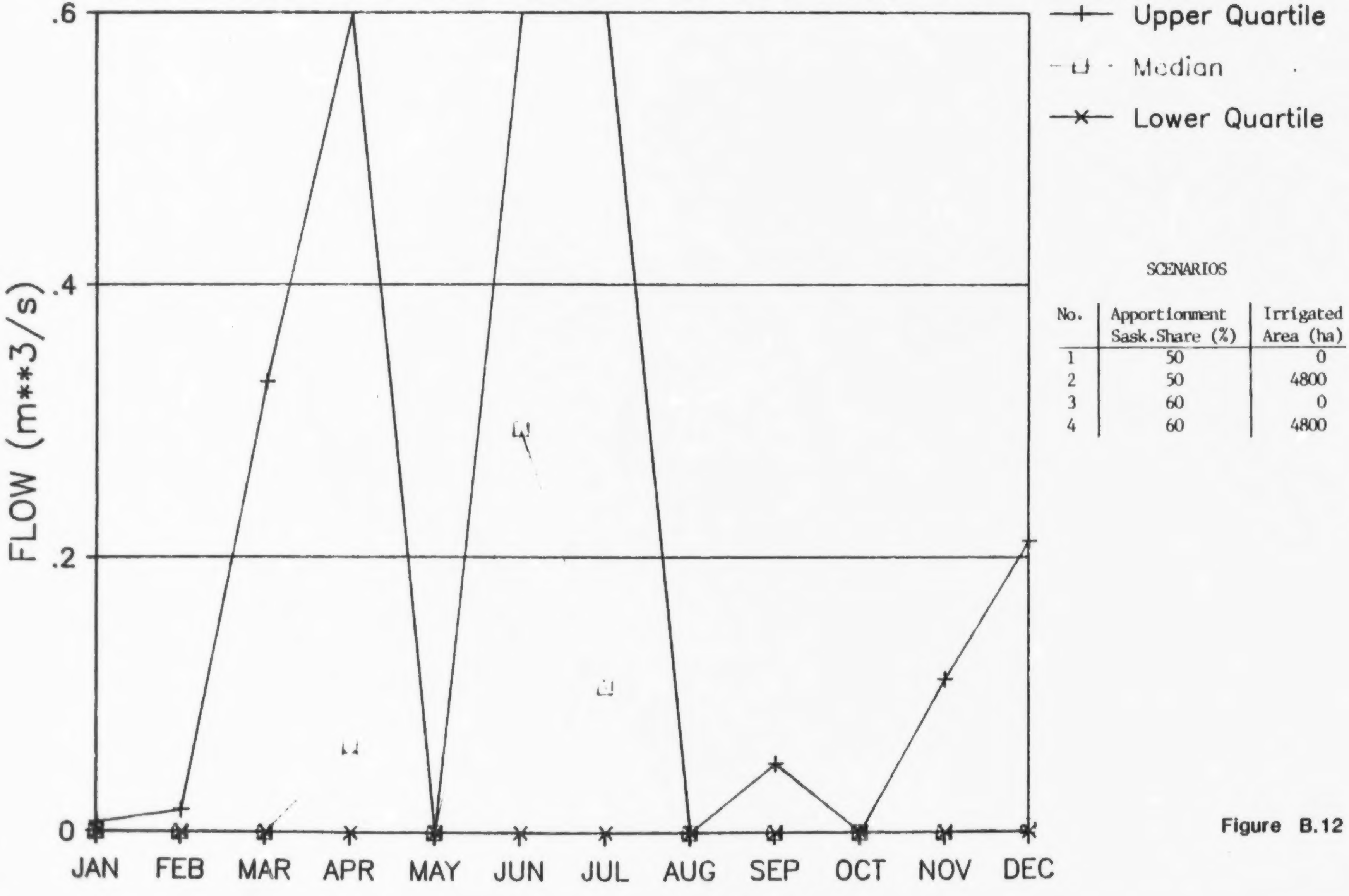
Moose Mountain Creek Below Alameda Reservoir – Scenario 2

SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.11

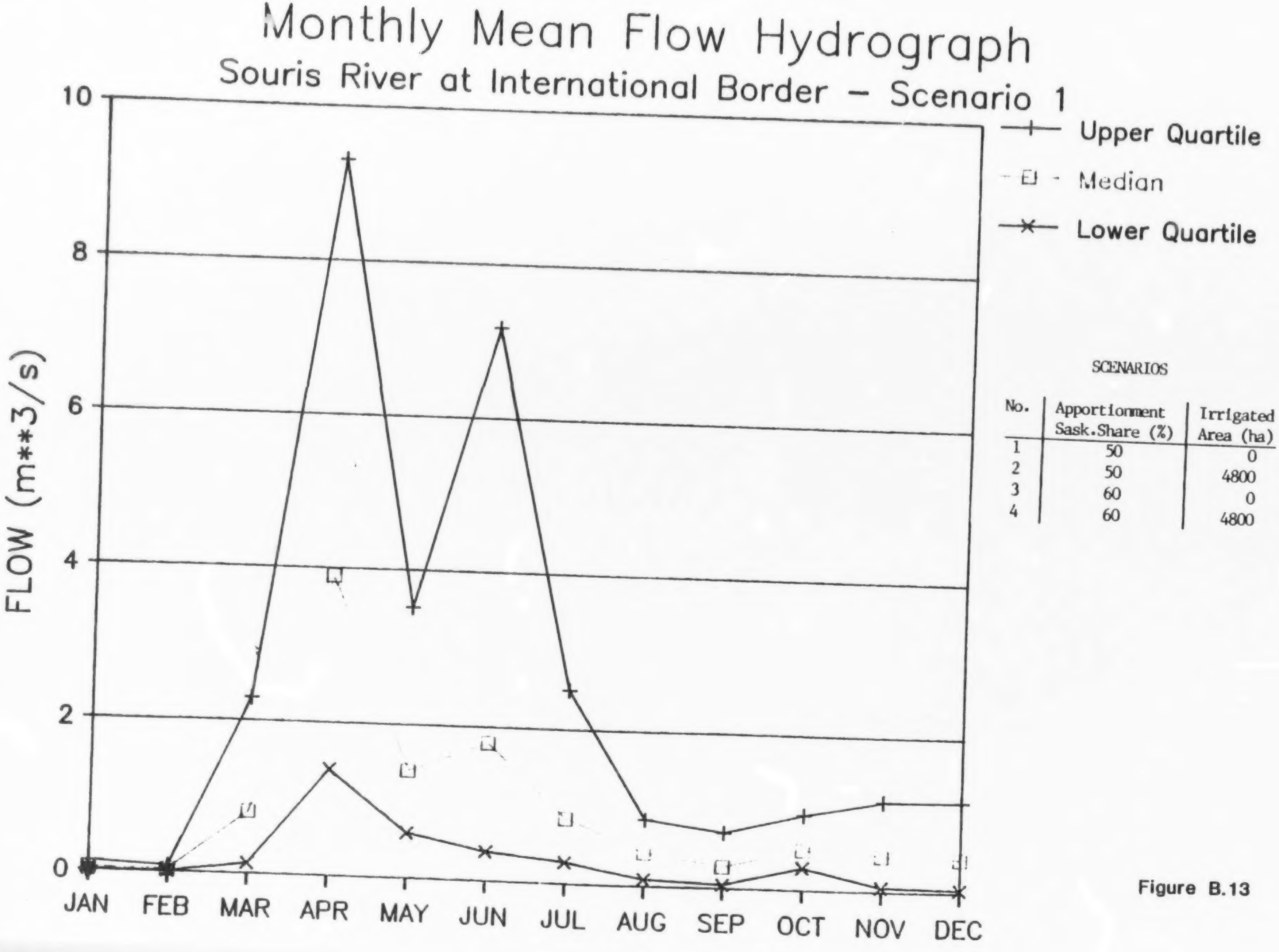
Monthly Mean Flow Hydrograph
Moose Mountain Creek Below Alameda Reservoir – Scenario 3



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.12



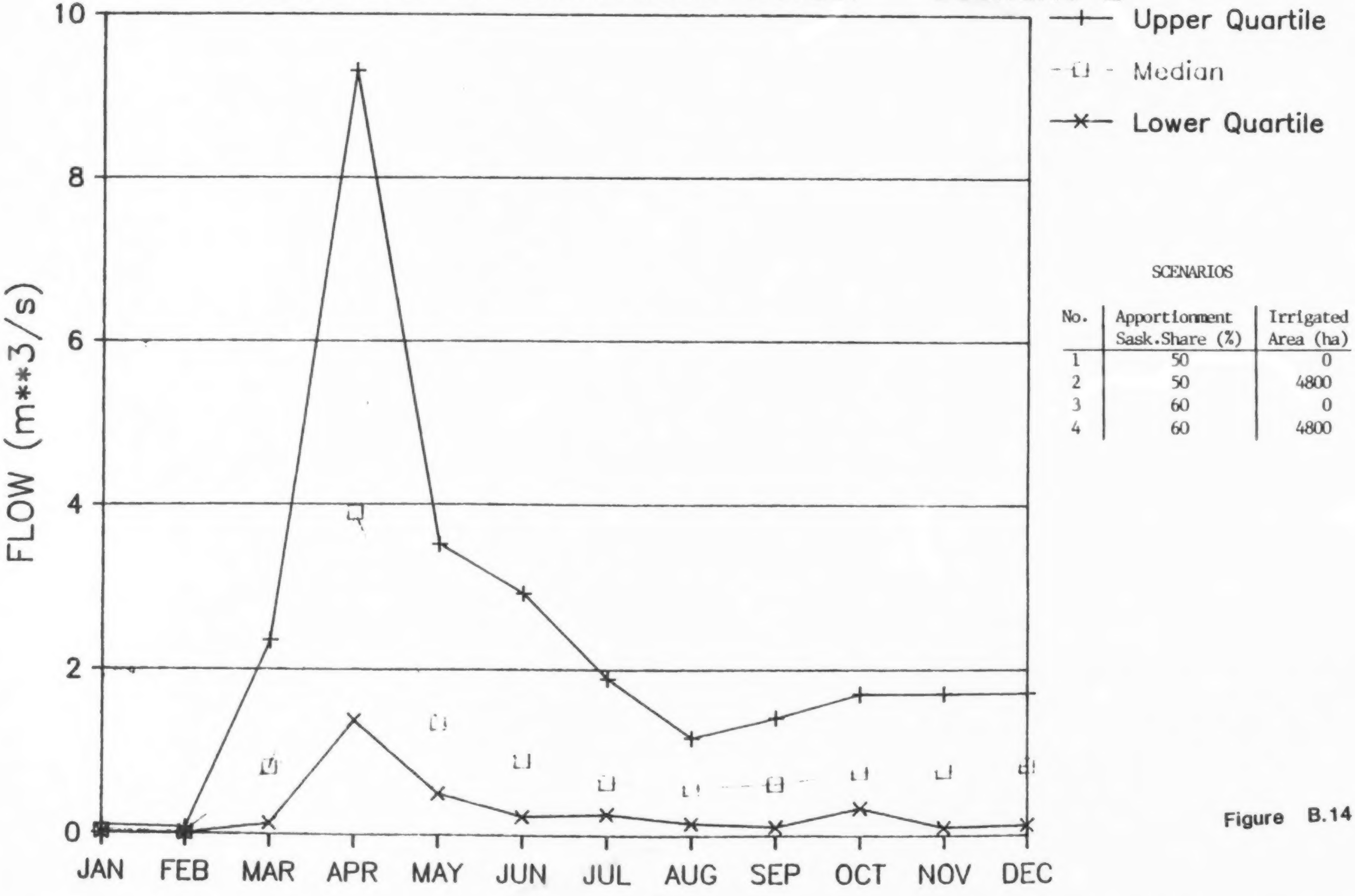
SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.13

Monthly Mean Flow Hydrograph

Souris River at International Border – Scenario 2

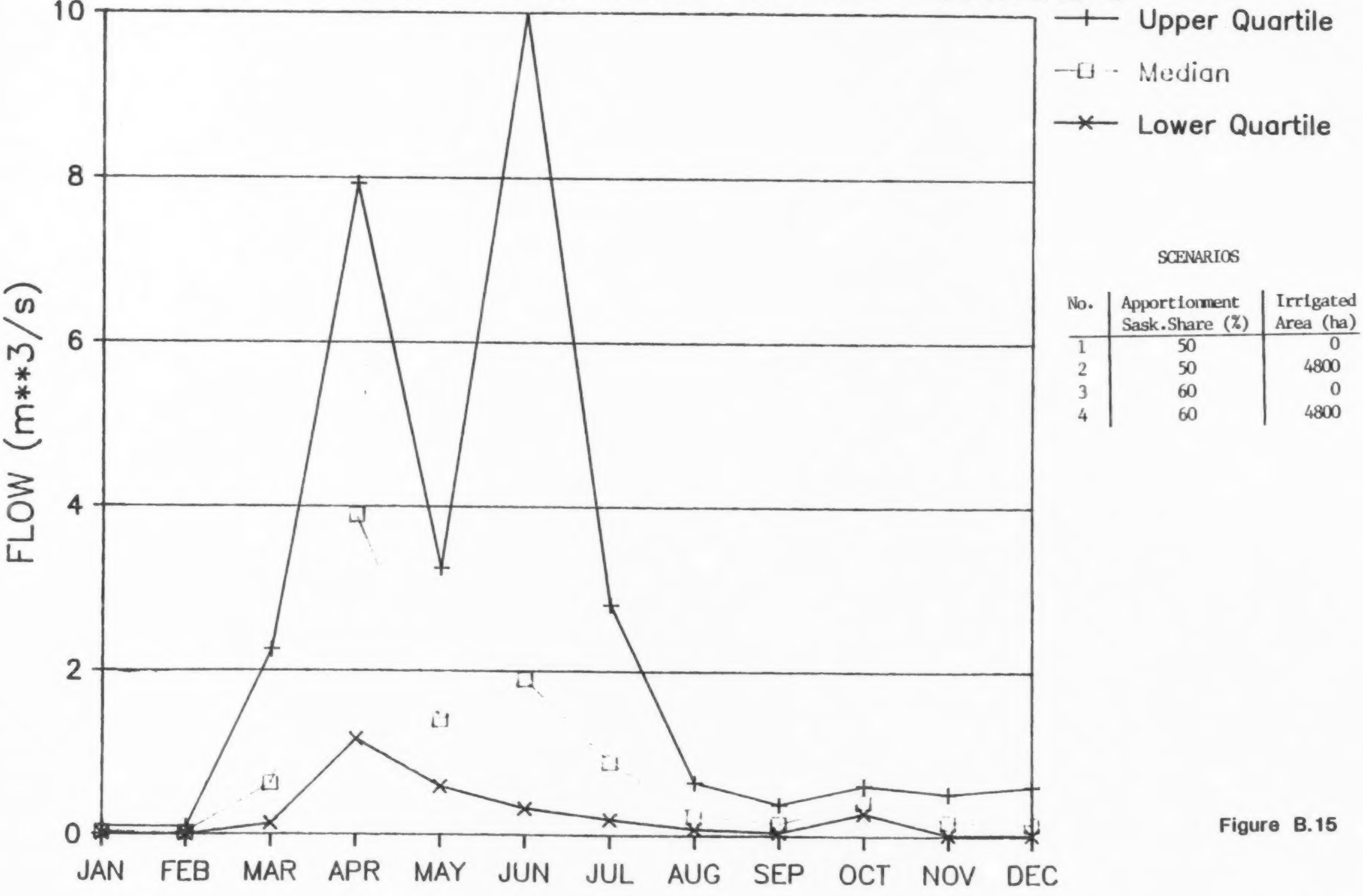


SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.14

Monthly Mean Flow Hydrograph
Souris River at International Border – Scenario 3



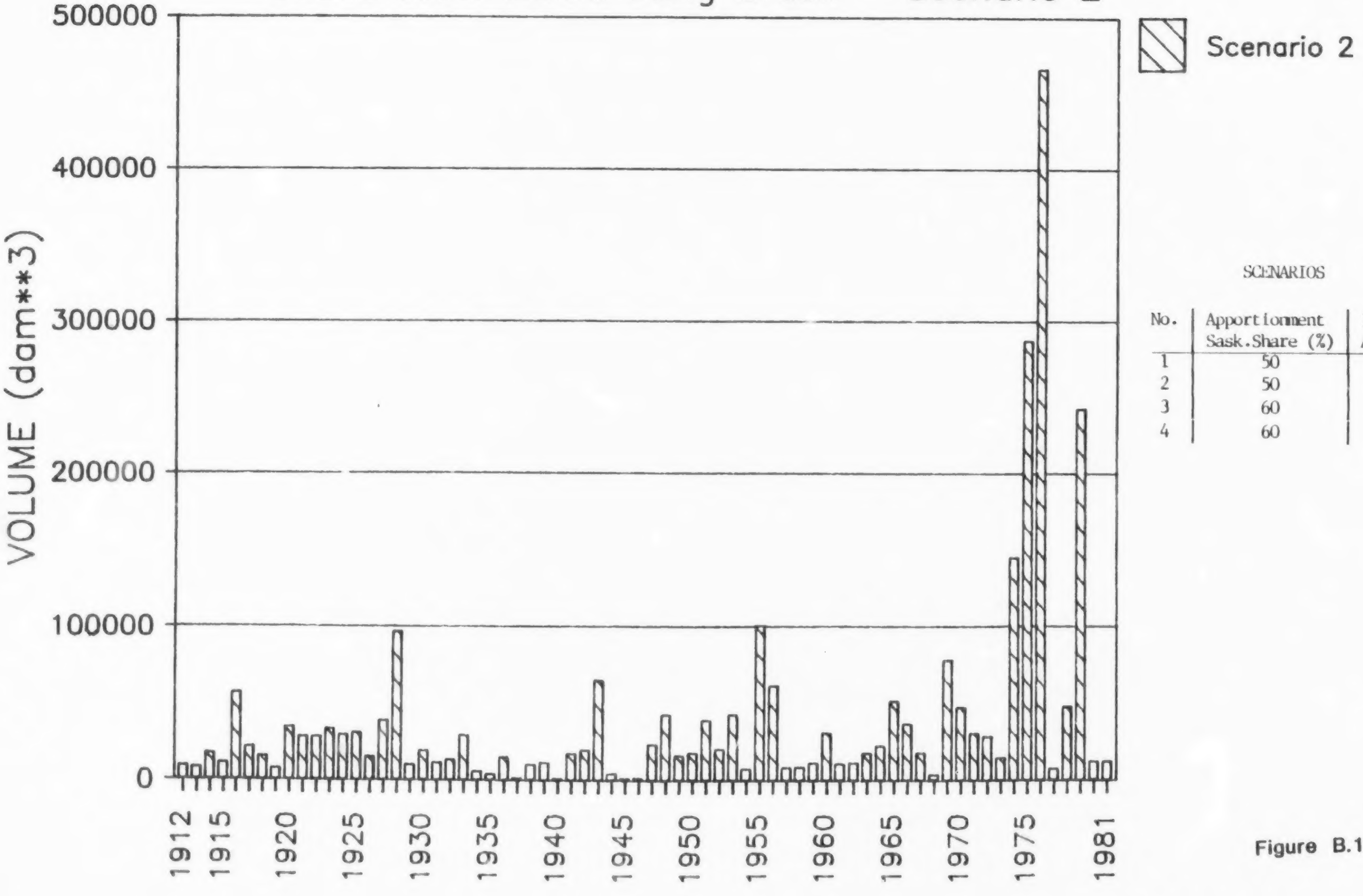
SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.15

Annual Volume

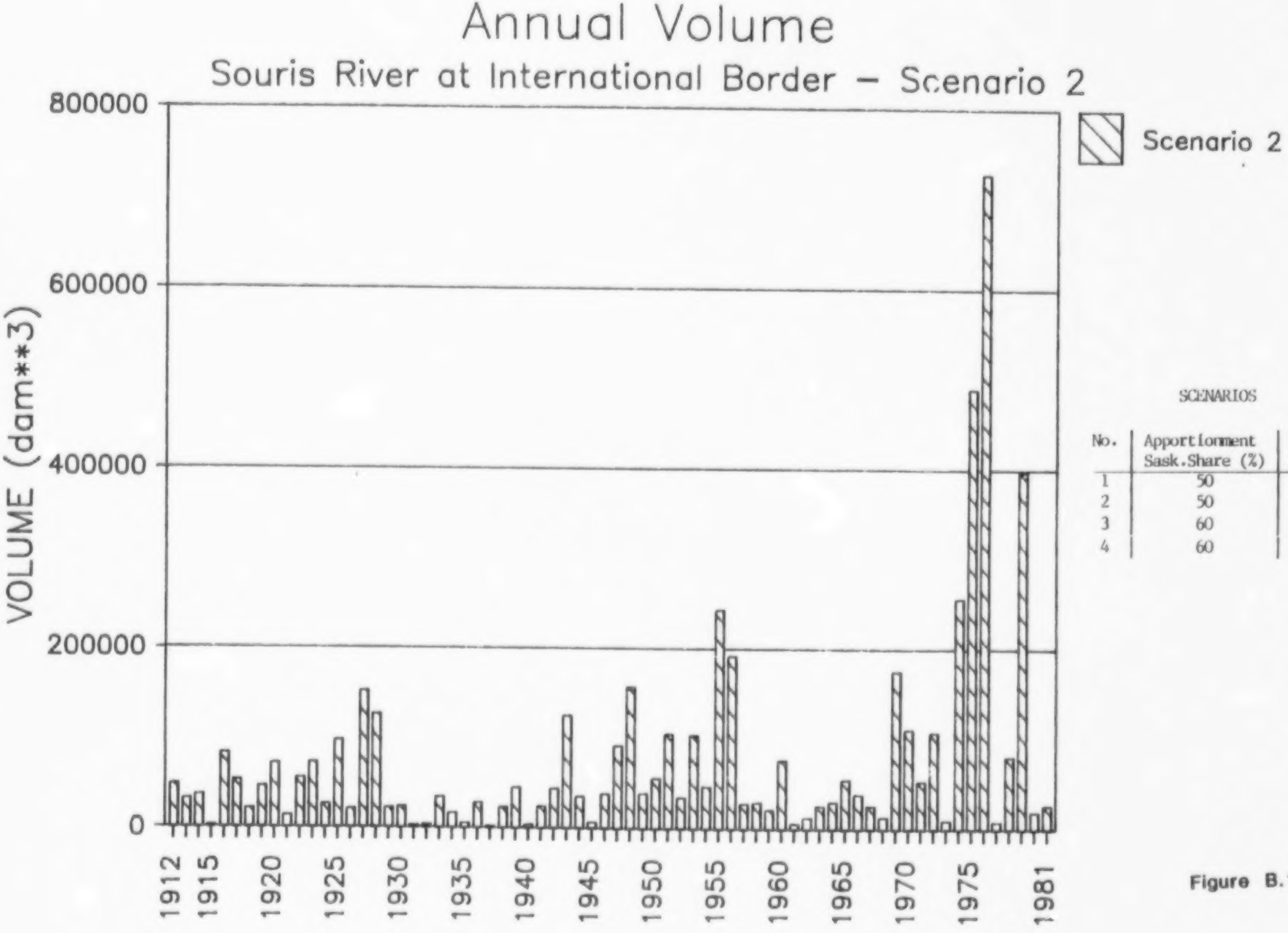
Souris River Below Long Creek – Scenario 2



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.16



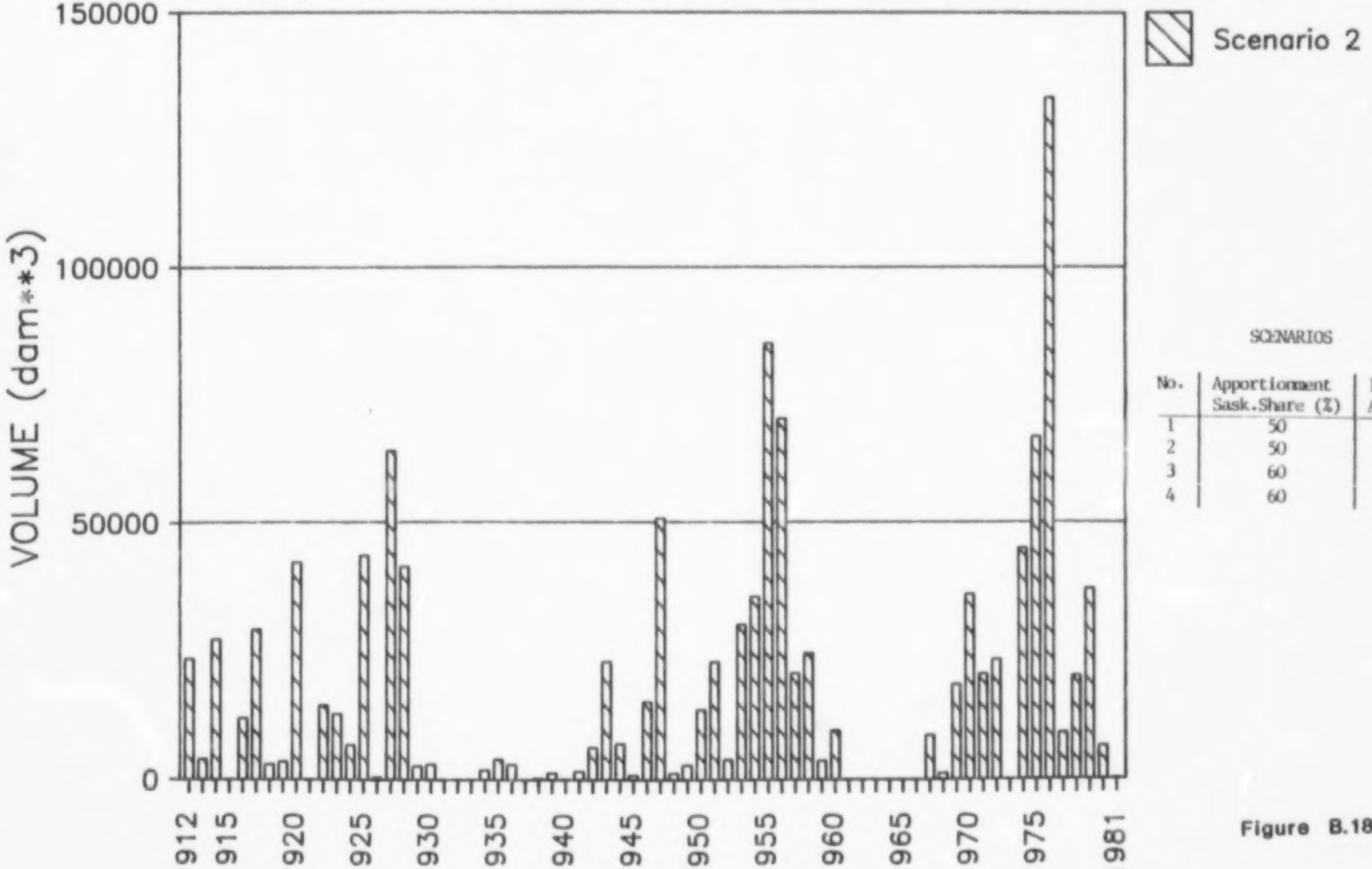
SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.17

Annual Volume

Moose Mountain Creek Below Alameda Reservoir – Scenario 2



SCENARIOS

No.	Apportionment Sask.Share (%)	Irrigated Area (ha)
1	50	0
2	50	4800
3	60	0
4	60	4800

Figure B.18

APPENDIX C

General Guidelines Respecting the Administration of Water Rights in the Souris River Basin

General Guidelines

Respecting the Administration of Water Rights in the Souris River Basin in Consideration of the Rafferty and Alameda Reservoirs Project

June, 1987

I INTENT OF STATEMENT

In consideration of the impact that the Rafferty and Alameda project could have in the basin, there is a need to establish guidelines by which to administer existing and new water rights. These guidelines are to provide for an orderly and fair allocation of new rights; preservation of existing rights where possible; and, preservation of the potential for the project to achieve the benefits for which it was originally designed. These guidelines will be administered in accordance with the provisions of The Water Corporation Act.

II BACKGROUND

The proposed Rafferty and Alameda dams and reservoirs and the Boundary to Rafferty diversion channel, defined as the Souris River Project, will allow Saskatchewan to control most of its share[1] of the natural flow of the Souris River basin to which it is entitled under the 1959 Interim Measures of the International Joint Commission.

Any water that runs off into the Souris River or its tributaries and is not stored or consumed by existing users, contributes to making up the annual portion of water that Saskatchewan must share with North Dakota. Once the Souris River Project has been constructed, the Rafferty and Alameda Reservoirs will be the major sources of water supply in the basin. The Souris River Project has been justified on the basis that sufficient opportunities will develop in the future to beneficially utilize that water. Because the Souris River Project will permanently or temporarily flood land upon which works are situated for the purposes of using a water right or will affect the supply to those works, it may be necessary to cancel or modify the existing water rights.

III BASIS OF COMPENSATION

Section 41 and 42 of The Water Corporation Act describe conditions under which a water right can be cancelled with the conditions varying depending on whether the water right was granted before or after the coming into force of The Act. The holder of a water right that is cancelled is eligible for compensation only if the water right was granted prior to the coming into force of The Act.

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[1] Generally, 50 percent of the annual natural flow of the Souris River in Saskatchewan.

Unless as otherwise specified in these guidelines, the compensation the holder of a water right is eligible for, shall be as prescribed in The Water Corporation Act provided that equivalent compensation has not already been provided for under a land purchase program.

For purposes of applying these guidelines, it is assumed that construction of the Rafferty Dam will be initiated within the next two years.

IV GUIDELINES

For the purposes of describing the guidelines, it is necessary to distinguish between a number of water users on the basis of how they will be affected by the Souris River Project. These distinctions are specified in classes only for the purposes of this document. There is no intended priorization or preference on the basis of class number.

Existing Users

Class (1)

These users include those that are authorized to use water in the basin where:

- the works are not situated on lands that will be affected by the Souris River Project; and,
- any operation of the Souris River Project will not affect the supply to the works. (These users generally divert water at locations upstream of the Souris River Project.)

These users will continue to hold their water rights under the conditions prescribed in the water right.

Class (2)

These users are defined as per Class (1) except:

- the supply at the works can be affected by operation of the Souris River Project. (These users generally divert water at locations that are downstream of the Souris River Project.)

These users will continue to have their water rights under the original provisions subject to Sask Water being able to operate the project in a practical and efficient manner. If an amendment to the water right is required to provide for the practical and efficient operation of the Souris River Project, then the holder of the water right will have the option of having their water right amended or having the water right cancelled. If it is cancelled, eligibility for compensation will be established as per section III.

Class (3)

These users include those that are authorized to use water in the basin where:

- the works are situated on lands that will be affected by the Souris River Project; and,
- any modification to the works would not fulfill the original designated purpose. (These users generally divert from locations that will be flooded by the reservoirs and the purpose will also be rendered useless as a result of the flooding.)

These water rights will be considered for cancellation and eligibility for compensation will be established as per section III.

Class (4)

These users are defined as per Class (3), except:

- a modification to the works would permit use of the water for the original designated purpose. (These users generally divert from locations that will be flooded and if the works were moved or redesigned the water could still be used in the manner that was originally intended, such as irrigating upland areas.)

These users will have the option of having their water rights cancelled or retained. If the water right is cancelled, eligibility for compensation will be established as per section III. If the water right is retained and the intent is to continue with the original intended purpose, the holder of the water right shall be eligible for compensation in accordance with section III or in an amount equal to the cost as determined by the Corporation to maintain the original purpose, whichever is the least.

Class (5)

The purpose is municipal.

These users will have the option of receiving compensation in accordance with section III or in the form of the least cost alternative to supply water to meet the provisions of the original water right.

New Water Rights

Class (1)

These include any potential user who intends to use water in the Souris River basin where:

- the works will be situated such that the supply at the works will be affected by operation of the Souris River Project. (These users will generally divert from locations downstream of the Souris River Project.)

  These users will only be considered for a water right after completion of the Rafferty Dam where the new use affects the Rafferty Dam and Reservoir operation and after completion of the Alameda Dam where the new use affects the Alameda Dam and Reservoir operation. The decision granting the water right will depend on the amount of water in storage in the Rafferty and Alameda Reservoirs and the special operation required of the Souris River Project as a result of the water right.

Class (2)

These include any potential user who intends to use water in the Souris River basin where:

- the works are situated in the effective drainage area; and,
- the supply at the works will not be affected by the operation of the project. (These users will generally be located upstream of the project.)

  These users will not be considered for a water right for a period of five years after the completion of construction of Rafferty Dam. This time period will be used to assess the potential demands that might develop to use the water in storage in the Souris River Project. This will also allow time to bring the reservoirs to suitable operating elevations. Exceptions to this guideline may be made where the allocation would be considered to have an insignificant effect on the water supply available to the Souris River Project or would be in the public interest.

Class (3)

These users are defined as per Class (1) except:

- the point of diversion is situated beyond the effective drainage area.

  These users will be considered for a water right under the provisions of The Water Corporation Act.